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# **Potential Business Markets for the Digital Circuit Breaker**

An Investigation of the Swedish Electricity Market

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AN INVESTIGATION OF THE SWEDISH ELECTRICITY MARKET

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Potential Business Markets for the Digital Circuit Breaker  
– an investigation of the Swedish electricity market

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# Abstract

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The following master thesis is conducted on behalf of The Royal Institute of Technology and Manetos AB with the purpose of investigating potential business markets for the new innovation, the Digital Circuit Breaker (DCB). The DCB is a mean for digitalising the distribution board, which is the middleman between households' electrical appliances and the electrical grid. Through this digitalisation, a two-way communication between households and the grid can emerge, creating possibilities for demand side flexibility and energy management. The technology also provides more transparency for homeowners and real estate owners into households' and buildings' energy consumption, through monitoring and disaggregation.

The study found that the energy landscape is facing significant challenges for the future. The integration of more intermittent energy, unpredictable energy consumption, new power consuming technologies and an aging grid were examples of challenges which potentially could jeopardize the security of electric supply. Many of these challenges however were also found to be issues which the DCB could potentially solve. It was also found that power-based tariffs spoke in favour of the DCB. Based on the overall empirical results, the study found that there is a need amongst utilities for demand side flexibility solutions and that there is a need amongst homeowners for electricity transparency and monitoring tools. This gives rise to a situation where the possibility to commercialize the DCB exists. By making the DCB a demand flexibility solution for utilities and a transparency and monitoring tool for homeowners, the needs for both utilities and homeowners can be fulfilled.

The recommendations towards Manetos were to focus on the business markets electric utilities, more specifically municipally owned grid companies, and homeowners. It was found that the municipally owned grid companies focused more on socioeconomics than profit based grid companies. Furthermore, the municipally owned grid companies that had power-based tariffs in place today showed great interest in the DCB as a tool for better managing electrical load and avoiding power peaks. For homeowners it was found that the people who owned electric vehicles or had direct electric heating showed great interest in an electricity management tool such as the DCB. The study also found real estate companies to be a business market of interest, however, not enough interviews were conducted in order to draw conclusions for the markets viability. Therefore, further investigation of the real estate company market is recommended.

# Sammanfattning

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Följande examensarbete har utförts på uppdrag av Kungliga Tekniska Högskolan och Manetos AB med syftet att undersöka potentiella affärsmarknader för en ny innovation kallad den Digitala Brytaren (DCB – Digital Circuit Breaker). DCBn är ett verktyg för att digitalisera elskåpet, vilket fungerar som en mellanhand mellan hushåll och elnätet. Denna digitalisering möjliggör för tvåvägskommunikation mellan hushåll och elnät, vilket öppnar upp möjligheter för efterfrågefleksibilitet och bättre energihushållning. Teknologin ökar även transparensen gällande byggnaders energikonsumtion, både för hushåll och fastighetsägare, genom övervakning och dissaggregering.

Studien fann att energilandskapet står inför betydande utmaningar inför framtiden. Integrationen av mer intermittent energi, oförutsägbar energikonsumtion, nya teknologier och ett åldrande elnät är några exempel på utmaningar vilka kan komma att äventyra leveranssäkerheten i systemet. Många av dessa utmaningar visade sig dock vara problem som DCBn skulle kunna lösa. Studien fann även att effektbaserade tariffer, vilka idag används som ett verktyg för att motverka höga effektuttag, fungerar som incitament för DCBn och för en mer hållbar energikonsumtion generellt. Baserat på de övergripande empiriska resultaten fann studien att det finns ett behov för efterfrågefleksibilitets lösningar bland elnätsägare, samt ett behov för transparens- och kontroll-verktyg för villaägare. Detta ger möjlighet för att kommersialisera DCBn. Behoven hos både elnätsägare och villaägare kan uppnås genom att paketera DCBn som ett efterfrågefleksibilitets-, transparens- och övervaknings-verktyg.

Rekommendationen till Manetos var att fokusera på kundsegmenten elnätsägare, främst de kommunalt ägda, samt villaägare. Studien fann att kommunalägda elnätsägare fokuserade mer på samhällsekonomi är de vinstdrivande elnätsföretagen. Vidare så fann studien att de kommunala elnätsägarna vilka idag använder effekt tariffer, hade ett stort intresse för DCBn som ett verktyg för att minska effekttoppar och uppnå bättre övervakning. För villaägare kunde det ses att de personer som ägde elbilar eller hade direktverkande el i bostaden visade störst intresse för ett verktyg såsom DCBn. Även kundsegmentet fastighetsägare visade sig vara av intresse, dock genomfördes inte ett tillräckligt stort antal intervjuer inom segmentet för att kunna dra slutsatser om marknadens lönsamhet. Därför föreslås undersökning av detta segment för vidare framtida studier, såväl som att undersöka potentialen för DCBn internationellt samt att inkludera ett större antal villaägare i studien.





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This master thesis does not only put an end to the five year long adventure that has been our studies at KTH - The Royal Institute of Technology, but also to our years in the classroom. We will forever cherish the memories KTH has brought us and it is with great pride that we receive our Master of science diploma. Before we begin our career as engineers, we would like to express our greatest gratitude to all who have contributed to this journey. First of all, we would like to thank our families for always supporting us, both with wisdom and food. Secondly, we would like to thank all of our friends for filling these past five years with laughter, joy and excitement.

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Tayvi out!



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## Abbreviations

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DCB	-	Digital Circuit Breaker
DIKW	-	Data, Information, Knowledge and Wisdom
EI	-	Energimarknadsinspektionen
ETIPs	-	European Technology and Innovation Platforms
EU	-	European Union
IoT	-	Internet of Things
NEPP	-	North European Power Perspective
SEOM	-	Sollentuna Energi och Miljö
SET-plan	-	Strategic Energy Technology Plan
SHE	-	Sala Heby Energi Elnät
SVK	-	Svenska Kraftnät

# 1. Introduction

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*The following chapter presents a background to the master thesis as well as why the subject needs to be investigated. Furthermore, the aim of the study is presented together with the main research questions. The chapter also includes the study's delimitations as well as the expected contribution.*

## 1.1 Background

The energy market today is expected to go through bigger changes in the upcoming five years than in the past fifty years together, where the fast paced development is being enhanced by external factors such as new technology, globalization and politics (Energimarknadsinspektionen, 2016a). Sweden is a country with high levels of energy use, both per capita as well as per unit BNP, which are derived from the cold climate, long transport distances, high material living standards as well as energy demanding industries (Bergman, 2014).

The Swedish energy politics aim to create good conditions for stable energy supply, which is both sustainable and contributes to the competitive business environment (Myndigheten för tillväxtpolitiska utvärdering och analyser, 2014). By 2020 the Swedish government has set a goal of reducing greenhouse gas emissions by 17% compared to 2005 levels (Regeringskansliet, 2017b). However, challenges for the energy market are emerging such as restructuring of the transport system, the future of nuclear power, the increased development of renewable energy and the design of the electrical grid (Myndigheten för tillväxtpolitiska utvärdering och analyser, 2014).

The Swedish electricity system is today facing challenges, both regarding infrastructure and electricity production (Energimyndigheten, 2015a). The amount of renewable energy production is increasing which impacts the operation of the power system, operational safety on the grid as well as maintaining balance (Svenska Kraftnät, 2015). This variable and intermittent energy production is dependent on external factors which makes it difficult to predict and control energy production (Energimyndigheten, 2015a).

Another challenge for the electricity system is uneven load and power peaks on the grid. By evening out load and shaving power peaks the capacity on the grid can increase and transmission losses can decrease (Energimarknadsinspektionen, 2015a). Furthermore, a trend for the energy system is that it is becoming more decentralized, with more distributed generation, energy storage and customer involvement (The European Parliament, 2010). Future challenges include integrating an electrified vehicle fleet, energy storage solutions and local micro production (Energimarknadsinspektionen, 2016a).

In a future energy market, with a high level of intermittent energy, it will become important to harness the flexibility resources in the energy system, i.e. flexible production, energy storage and demand side flexibility (Energimarknadsinspektionen, 2016a). The customer has

an important role in the future energy system, as they will be able to make active choices and affect their electricity consumption (Energimarknadsinspektionen, 2016b). Demand side flexibility entails that customers adapt their electricity consumption based on signals, such as when the load on the grid is high, when there is a lot of intermittent energy available or when the electricity price is low. Demand side flexibility is seen as a potential solution towards the challenges that the electricity system is facing (Energimarknadsinspektionen, 2016a).

## 1.2 Problematization

When customers begin to engage in demand side flexibility the electricity market will be affected. However, according to Energimarknadsinspektionen (Ei – Swedish Energy Market Inspectorate), customers today do not have a lot of prior knowledge of demand side flexibility nor do they know their potential for demand side flexibility. Furthermore, there exist a limited amount of smart control instruments for demand side flexibility and these instruments are not common to have in households today. Ei also see current market hinders for demand side flexibility, for example not allowing customers to sell their flexibility on the market (Energimarknadsinspektionen, 2016b).

Manetos AB, which today offer a smart heat control device, have developed a technology which allows for power control and facilitates demand side flexibility, namely the Digital Circuit Breaker (DCB). The DCB is a digitalised version of a traditional circuit breaker. It is installed in a buildings distribution panel and allows for communication between households and the electrical grid, monitoring of households' energy consumption and disaggregation of appliances. The product is currently undergoing a development phase and there exist no similar products on the Swedish market. As circuit breakers are the middleman between the electrical grid and energy consumers, the potential markets and applications for the DCB are many.

## 1.3 Purpose and Research Questions

The purpose of the following research is to investigate potential business markets for the DCB in Sweden. Based on the background, problematization and purpose of the thesis the main research question is:

- What are potential viable business markets for the DCB?

To answer the main research question, two sub research questions will be investigated:

- What challenges and future trends do customers in each viable market face?
- What driving factors will facilitate vs. impede the commercialization of the DCB?



## 1.4 Delimitations

The following study will only focus on the DCB as a power control instrument and does not discuss any other smart instruments for controlling power or demand side flexibility. Furthermore, the technical aspect of the DCB, how it works and the components behind it, will be left out of the investigation.

Challenges that are presented will be based on the Swedish energy system, its infrastructure and market players. There exist many challenges for the energy system today, however the focus of this report will be challenges that are related to the electrical grid. Therefore, the literature that is studied will be focused within this area.

The studied sample of actors will be the largest within the utility and homeowner area, however the study also includes a scan of the real estate market as well as electricity retailers in order to present a better overview. Furthermore, the markets that will be investigated are based in Sweden and interviews that are conducted are with companies and actors in Sweden. The international perspective and potential for DCBs has been chosen not to be included in the scope of the following thesis.

## 1.5 Expected Contribution

The following thesis will provide an introduction of a new, and potentially disruptive, technology called the Digital Circuit Breaker (DCB). As the DCB is not yet fully developed, nor released to the Swedish market, there exists no previous information regarding where the product could be successful or which actors that it could be of interest for. This study will therefore contribute to identifying areas where a need for electricity management solutions such as the DCB exists. This will be done by a through scan of existing literature and research studies, as well as through interviews with different actors on the electricity market, such as consumers, producers, retailers and agencies. Interviews with impartial actors such as researchers and experts within the field of electricity distribution, usage and future trends will also be included. Furthermore, this study will investigate in which ways the DCB, or similar electricity control solutions, can solve issues that each customer segment face.

The conducted study will also contribute to adding a new dimension to the current knowledge of the Swedish electricity market and the area of demand side flexibility. By conducting interviews with different stakeholders who could potentially be interested in the DCB or similar solutions, the study will cover overall perceptions towards demand side flexibility tools from different angles and actors. Furthermore, the conducted interviews will contribute with better insight into each actors' positioning towards future challenges for the energy system. The study will increase the knowledge of the electricity actors' beliefs for the future energy system and its future design of roles and responsibilities.

The outcome of this study can be used in future research projects as the empirical results will have a good level of generalizability, meaning that the results can be applied and assessed in other studies within the field of electricity control, the Swedish energy market, demand side

flexibility, future development for the energy market or smart energy-technologies. Thereby, the expected contribution of this study will be quite broad in aspects of sharing a lot of assessed information, as knowledge, to other researchers.

## 1.6 Thesis Outline

**Chapter 2 – Methodology:** This chapter presents the chosen research design for the study as well as the chosen research process. Each step of the research process is described in detail, including a description of the chosen case study as well as an overview of the interviewed actors. Furthermore, the analysis method of the results is described, including evaluation of the reliability and validity of the study.

**Chapter 3 – Literature Review:** This chapter contains a literature study, which presents the existing relevant research that has been used for the study. The literature study also includes the theoretical framework that was used for presenting and analysing the empirical results.

**Chapter 4 – Results:** This chapter is divided into two parts, namely a case study and empirical results. The case study presents a background for the DCB and why the area is of importance to study. The empirical results present the results from conducted interviews, where the outcomes are presented in tables, diagrams and text.

**Chapter 5 – Discussion and Analysis:** Findings from the empirical results are discussed and analysed according to the chosen theoretical framework, with supporting research and figures.

**Chapter 6 – Conclusions:** In this chapter conclusions and recommendations are presented based on the study's empirical results, discussion and analysis.

## 2. Research Methodology

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*The following chapter presents the research methodology used in the study. The chosen research design and research process will be presented as well as how the data collection and analysis were conducted. Finally, an assessment of the study's generalizability, reliability and validity will be presented.*

### 2.1 Research Design

Since the purpose of the research was to investigate potential business markets for the digital circuit breaker (DCB) in Sweden, an explanatory case study was chosen as research approach. Collins & Hussey (2014) explain explanatory research as being conducted when there is little previous research of the problem at hand. The approach aims to search for patterns and ideas, as well as develop hypothesis (Collins & Hussey, 2014). As the DCB is a new invention, previous studies within the area are limited. According to Blomkvist & Hallin (2015) an explanatory approach is fitting when an unexplored area is being researched. The explanatory approach assesses if existing theories and concepts can be applied to the problem, or if new ones have to be developed (Collins & Hussey, 2014), making the method fitting for the purpose of this thesis.

Case studies are used when new dimensions are to be discovered and when the purpose of a study is of the explanatory kind (Blomkvist & Hallin, 2015), which is why the research in this thesis was designed according to a case study. Case studies are very flexible and they can generate both qualitative and quantitative data (Collins & Hussey, 2014). Just as with the explanatory research method, a case study is useful when variables are still unknown and the studied phenomenon not completely comprehensible (Voss, Tsikriktsis, & Frolich, 2002). The method offers the possibility of a detailed empiricism where the complexity of reality can be better utilized (Blomkvist & Hallin, 2015). As the area of the DCB is new, a case study provides an opportunity to discover new aspects of the subject.

For this study, an inductive research design was chosen, meaning that theory was generated from emerging data (Blomkvist & Hallin, 2015). An inductive research design is, according to Collins & Hussey (2014), often associated with an explanatory purpose and case study technique. Inductive research allows for theory to be developed from observations of empirical reality (Collins & Hussey, 2014). Allowing empiricism to generate theory is fitting when the research area is uncharted, such as in the case with DCBs.

*Figure 1* presents the Data, Information, Knowledge and Wisdom hierarchy (DIKW hierarchy). The following study was chosen to have an observing and consultancy based approach where the aim was to explain the phenomena at hand. The following research therefore focuses mainly on the *information* and *knowledge* layer of the DIKW hierarchy, highlighted in *Figure 1*. The DIKW hierarchy falls within the area of information science and management, and illustrates how wisdom is the highest level of the hierarchy, which also is the most difficult to achieve. Below wisdom, comes knowledge, information and data. Data,

often being large in volume, is funnelled down into a smaller amount of information, and an even smaller amount of knowledge and wisdom. The hierarchy assumes that data can create information, which can be used to create knowledge which in turn can create wisdom (Rowley, 2007).

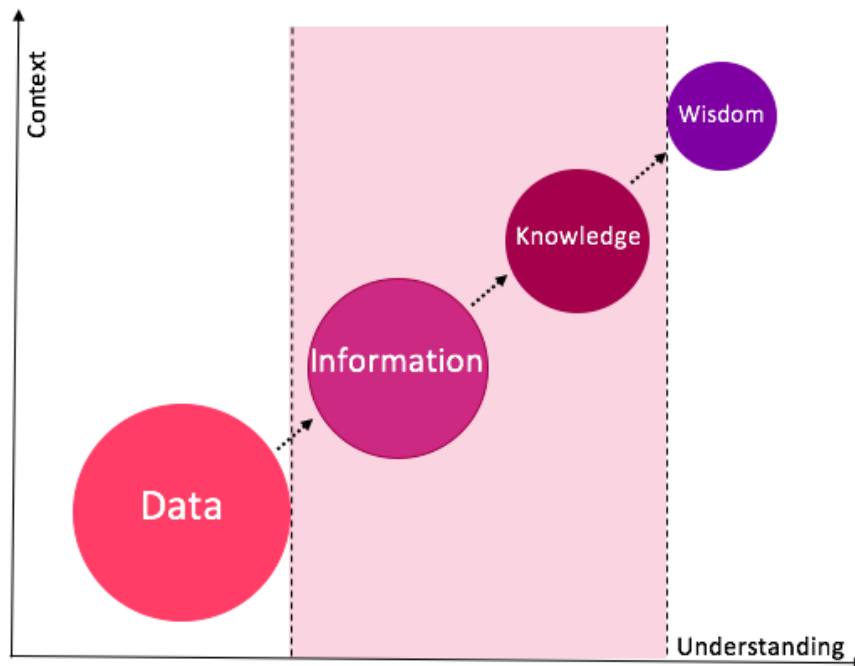


Figure 1. *Illustration of the DIKW hierarchy.*

## 2.2 Research Process

The research for this study has been an iterative process with continuous alterations to the research questions, purpose and literature review, as new discoveries were made along the research process. According to Blomqvist & Hallin (2015) this working process is common in case study research and usually generates more thorough results.

The case study has been divided into four main parts, illustrated in *Figure 2*, according to Collins & Hussey’s (2014) breakdown of case study methodologies. The research problem was first brought forward together with the client, Manetos, and KTH, however the scope of the study was narrowed down during the research process as more investigation was done on the subject. The activities in the case study have therefore been conducted iteratively.



Figure 2. *Case study method.*

### 2.2.1 Case Selection

The selection of the case study was made together with Manetos, whom is experiencing the phenomenon which was aimed to be studied. The scope was not set by the company meaning that there was a lot of freedom in deciding which area to focus on. Together with the client and KTH, certain limitations were set and two main markets were identified as interesting to investigate. The two markets identified were *end customers* and *grid owners*. When conducting the literature study, however, the list of interesting markets to investigate grew which is why *real estate companies* and *electricity retailers* were added to the list as potential markets for the DCBs. These four potential markets became subject of the conducted case study.

### 2.2.2 Preliminary Investigation

The preliminary investigation is the process of familiarizing with the context in which research will be conducted (Collins & Hussey, 2014). As the DCB is a new invention the initial phase of the investigation consisted of interviews with the engineers and inventors behind the idea, all of which work at Manetos. The interviews were unstructured which according to Blomkvist & Hallin (2014) creates opportunities to freely explore the area and increase knowledge. Studies of the current circuit breaker market and its market players, as well as the electrical grid and future trends were also reviewed. The aim of reviewing these studies was to understand the context in which the studied phenomena exists. The primary sources that were used were annual reports and research reports as well as through discussions and interviews with Manetos.

The second part of the preliminary investigation consisted of a literature review. The literature review aims to present which literature already exists on the subject and how it can support the material that is collected in the investigation (Blomkvist & Hallin, 2015). In order to conduct the literature review, sources such as e-sources, academic journals, books, articles, conference papers and industry data was used. The literature review included research on energy management and the electrical grid as well as challenges and future trends for the Swedish energy market. As the DCB is still under progress, it was deemed crucial to study future trends and developments for the energy market. The DCB should be able to harness the future potential and easily be adaptable to changes in energy landscape.

Another aspect of the literature review consisted of information about value creation and disruptive innovation. Disruptive technologies, such as the DCB itself, open up opportunities for business model innovation, especially when the company is a start-up. This area was also deemed crucial to understand as the purpose of the study was to find where the DCB fulfils a specific need for a specific market.

### 2.2.3 Data Collection

Eisenhardt (1989) suggests that the best way to collect data is through a combination of methods, such as archive searching, interviews, questionnaires and observations. The data that is collected can be of both quantitative and qualitative character. Qualitative data is associated with “words” and quantitative data with “numbers” (Collins & Hussey, 2014). There are strengths to collecting both qualitative and quantitative data. Quantitative data can indicate relationships that are difficult to identify for the researcher whereas qualitative data helps understand underlying relationships and theory, which can be used to strengthen quantitative research (Eisenhardt, 1989). In this case study a large part of the data collection is of the qualitative kind, mainly gathered through interviews.

#### *Interviews*

The interviews were conducted in a semi-structured manner. Semi-structured interviews mean that certain questions are prepared in beforehand, with follow up questions emerging based on the answers given (Collins & Hussey, 2014). The semi-structured method was deemed to be appropriate for this study as many of the interviewees were previously unaware of the DCB, allowing for external input and thoughts on the idea. When interviewing experts and researchers that were not seen as stakeholders, the interviews were both semi structured and discussion based. Conducting interviews is a good method for learning how individuals reason around different topics and issues, as well as opening up opportunities for new dimensions and aspects of the problem (Blomkvist & Hallin, 2015). For this study, many stakeholders were identified, see *Figure 3*. However, during this project the study came to focus on two main stakeholders, namely customers and state & municipality, marked with grey boxes in *Figure 3*.

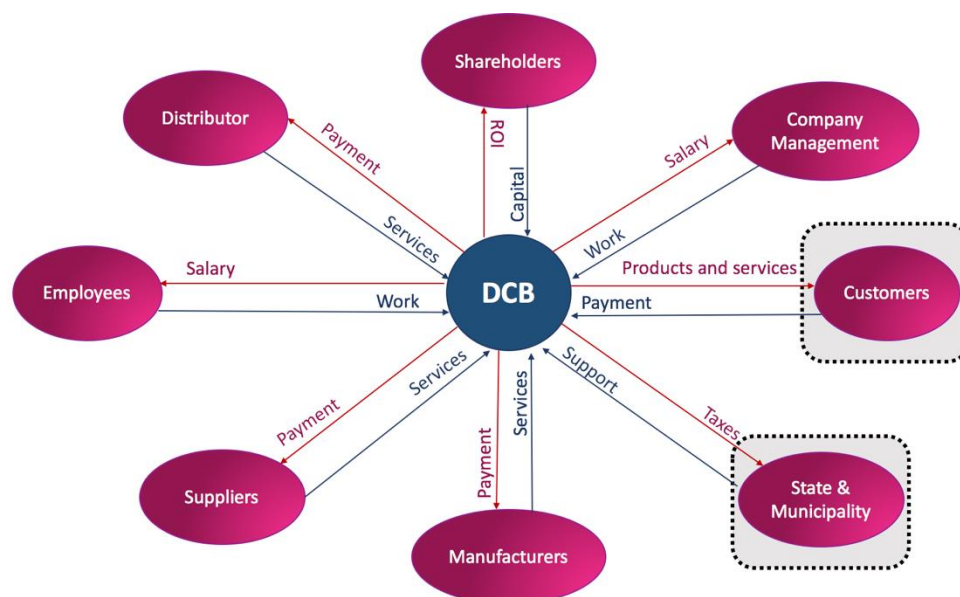


Figure 3. *Stakeholders for the DCB.*

Actors that were interviewed in the *customer*- and *state & municipality*- segment are presented in *Figure 4* as sub-segments. *Figure 4* illustrates an overview of the identified actors within the *customer* segment and the *state & municipality* segment. For each sub-segment (utilities, electricity retailers, real estate companies, homeowners and agencies) several interviews were conducted with different companies and people. *Table 1* provides more in depth information of the people who were interviewed within each sub-segment. Appendix A further presents a brief background for all interviewed companies/agencies.

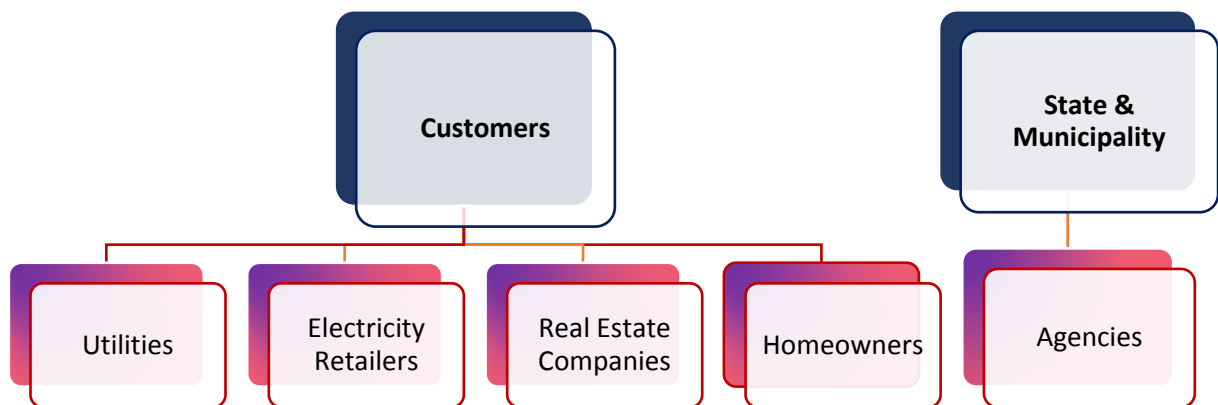


Figure 4. *Identified actors within the researched stakeholder segments.*

Table 1. *Details of interviews and interviewees.*

Name	Position	Company	Customer Segment	Pers. comm
Carl Johan Wallnerström	Senior advisor, Ph.D. Electrical Engineering	Energimarknadsinspektionen (Ei)	Agency	Semi-structured (appendix B)
Olle Hansson	Head of Technology and Development	Ellevio	Utility	Semi-structured (appendix C)
Johan Ribrant	Manager Business to Business	Ellevio	Utility	Semi-structured (appendix C)
Marielle Lahti	Director of Smartgrid and Electricity Markets	Swedish Smartgrid	Agency	Semi-structured (appendix B)
Björn Björnsson	Market Analyst	GodEL	Utility	Semi-structured (appendix D)
Anonymous	Electrical Engineer	Akademiska Hus	Real estate company	Semi-structured (appendix E)
Michel Thomas	Head of Business Management	E.ON	Utility	Semi-structured (appendix C)
Lennart Söder	Professor in Electric Power Systems	KTH	Expert and researcher	Semi-structured /discussion
Thorstein Watne	Business Strategist	Vattenfall	Utility	Semi-structured (appendix C)
Rebecca Nilsson	Senior Advisor Market Design	Svenska Kraftnät	Utility	Semi-structured (appendix C)
Linda Werther Öhling	Analyst	Svenska Kraftnät	Utility	Semi-structured (appendix C)
Anonymous	Analyst	Anonymous Investment Company	Expert and researcher	Semi-structured /discussion
Cajsa Bartusch	Researcher	Uppsala University	Expert and researcher	Semi-structured /discussion
Marcus Henriksson	Professional Service Manager	Fortum Charge and Drive	Utility	Semi-structured (appendix C)
Oscar Willén	Electrical Engineer and Project Manager	Sala Heby Energi Elnät (SHE)	Utility	Semi-structured (appendix C)
Thomas Anderson	Project Manager	Vectura Fastigheter	Real estate company	Semi-structured (appendix E)
David Holmbom	Business Development Manager and Electricity Trader	Sollentuna Energi och Miljö (SEOM)	Utility	Semi-structured (appendix C)
Stefan Braun	Vice President	Bixia AB	Utility	Semi-structured (appendix D)



#### 2.2.4 Data Analysis

The data analysis was done by a non-quantifying method, in a general analytical procedure presented by Collins & Hussey (2014). The procedure included three activities, that were to be done simultaneously: reduce the data, display the data, draw conclusion and verify the validity of those conclusions.

Data reduction refers to the selection and simplification of relevant information (Collins & Hussey, 2014). Since several topics were covered during the conducted interviews, a lot of information had to be screened in order to determine which information to use and which information to discard. The information gathered from the interviews was sorted according to four main subjects, namely *Challenges*, *Future trends*, *Supporting factors for the DCB* and *Risks/Barriers for the DCB*. The data that did not fit these categories was not included in the data analysis.

Displaying data refers to a visual presentation of information, which enables the reader to follow drawn conclusions from complex data (Collins & Hussey, 2014). The visual presentation of the data collected in this study was presented in tables and diagrams in order to provide a simple overview of the different stakeholders' views on the subject.

The conclusions of the study were drawn after the empirical results and discussion chapter had been documented. Hypothesis regarding the conclusions were made iteratively during the research process, but they were not answered completely until the very end, when all the data had been analysed.

### 2.3 Evaluating Analysis

Once a method of analysis has been selected and applied, it is important to know how to evaluate the analysis. According to Collins & Hussey (2014) many authors suggest various criteria that can be used when evaluating an interpretivist study and these can also be used to judge the quality of the analysis. Examples of the criteria used for this study are presented below.

#### 2.3.1 Credibility

Credibility means that the research has been conducted in a way that the subject of the study has correctly been identified and described. Researchers can improve the credibility by, for example, involving themselves in the study for a longer period of time, by persistent observation of the subject to obtain in depth understanding or by triangulation (Collins & Hussey, 2014). Since the research process of this study had a time limit, the study had to rely on interviews and literature reviews, which together have laid the ground for the credibility of the study. The preliminary investigation was also part of further increasing the credibility, since it gave the research enough information to find all angles of the studied phenomena and understand which potential markets that would be good to investigate. The credibility of the study could have been further investigated if the research process had continued over a longer

period of time, since that would give the possibility to conduct more in-depth case studies within each investigated market.

### 2.3.2 Triangulation

Triangulation means that the researcher includes different sources and collection methods of data. Using multiple sources of data, different research methods or even more than one researcher to investigate the same phenomena in one study helps to reduce the bias in data sources, methods and investigators (Collins & Hussey, 2014). This way, the validity of the research is assured. The purpose of triangulation however, is not necessarily to cross-validate data but rather investigate the phenomena from different perspectives (Tabassum, 2014). The data collection for this study has come from both interviews and sources such as e-sources, academic journals, books, articles, conference papers and industry data. There were in total 18 interviews (excluding homeowners) with different market players such as utilities, agencies, experts, real estate companies. The variety of interviewees gave the study numerous angles to work from, which is very good from a triangulation point of view. By interviewing so many people with different stakeholder roles, and by conducting such an in-depth literature review, the risk for bias was reduced.

### 2.3.3 Transferability and Generalizability

Transferability is a measure of how well the study's findings can be applied to other situations that are sufficiently similar to permit generalization. Generalizability is the degree of which the research findings can be extended to other cases or other settings (Collins & Hussey, 2014). According to Blomkvist & Hallin (2015) a case study can never result in statistical generalizability since the basis of studying one case cannot assert that the findings, with any statistical probability, will apply to all other cases, even if they are similar. However, case studies can result in analytical generalizability, meaning that it can be discussed how the results of the case study may be applicable to other, similar cases (Blomkvist & Hallin, 2015). The transferability and generalizability of this study is high since a large part of the empirical results as well as the discussion and analysis is a mapping of different stakeholders' take on the energy market, future developments and also new technology. Even though the case study has a focus on the DCB it can be generalized and applied for similar technologies that have an electricity monitoring function.

### 2.3.4 Confirmability

Confirmability is concerned with whether the research process has been well described and if it is possible to assess whether or not the findings flow from the data (Collins & Hussey, 2014). Trochim (2006) describes confirmability as to what degree the results of the research can be confirmed or validated by others. Trochim describes several ways to strengthen confirmability. One way is for the researcher to document all procedures for checking and rechecking data throughout the study. Other examples can be to let another researcher examine the results or to conduct a data audit after the study, by evaluating the data collection method or analysis procedures, and by that judge if there are any potential bias or distortion (Trochim, 2006). Strengthening the confirmability of this study has been done by letting

other master students read the report. This was a mutual agreement where four other students, during two different occasions, gave feedback on this study and in return feedback was given on their work. Furthermore, the empirical results were sent to all interviewees for approval, before continuing analysis and discussion. This gave interviewees the opportunity to correct certain errors, as well as modify citations from themselves. Apart from this, the study has been supervised by KTH with continuous follow ups during the research process. This way, the research process has been under scrutiny by a large number of people over a long period of time, which increases the confirmability of the study.

## 2.4 Reliability and Validity

Authors Collin & Hussey (2014) defines reliability as the accuracy and precision of the measurement and the absence of differences if the study were repeated. Validity refers to the extent to which a test measures what the researcher wants it to measure and the results reflect the phenomena under the study (Collins & Hussey, 2014). Blomkvist & Hallin (2015) consider validity to entail studying the right thing while reliability entails studying it in the right way. The authors further argue that high reliability does not mean that the research has high validity per say, but that high validity often pre-requires high reliability (Blomkvist & Hallin, 2015). Having high reliability and validity makes the research more credible and ensures that if the research was repeated, the results would be the same (Collins & Hussey, 2014).

Collins & Hussey (2014) describe several different ways for how the validity of a study can be assessed. The most common method is face validity, which simply means that the tests/measures used in the research do actually measure or represent what they are supposed to measure or represent. Another way to assess the validity, especially within business research, is through construct validity. This relates to the issue of non-observable phenomena, such as motivation, satisfaction, ambition and anxiety. These non-observable factors are known as hypothetical constructs, which are assumed to exist as underlying factors that explain observable phenomena (Collins & Hussey, 2014). The validity of this research has been assessed through construct validity since the studied phenomena was non-observable. By using a theoretical framework, the collected data could be analysed in an objective way, contributing to the assessment of validity.

Reliability can be assessed in an arithmetic or dialogical way. Arithmetic reliability means that reliability is measured mechanically after the observers have reached an agreement while in dialogical reliability there is unambiguity in the interpretation of the empirical material (Blomkvist & Hallin, 2015). Collins & Hussey (2014) mean that qualitative data is associated with a lower degree of reliability, since it is dependent on the context. Since this study included interviews, which is qualitative data, it was a challenge to maintain strong reliability. Therefore, many interviews were conducted within two main markets, namely utilities (including agencies) and homeowners, in order to achieve a large sample that represented the segments. A lot of the information identified in the literature review was also connected to the two market segments, which meant that those market segments have strong

reliability. For the remaining market segments that were studied (real estate companies and electricity retailers) the reliability is lower since the sample of interviewees is quite low and not as much information about the actors was found in the literature study. Recommendations for further studies include more interviews with real estate companies and electricity retailers.

### 3. Literature Study

The following chapter presents an overview of the theory and information that was identified as important for this research. The information presented is used in order to form a basic understanding of the Swedish energy market, the challenges that it faces and how it can be made more sustainable. The chapter also include a presentation of the theoretical framework used in this study.

#### 3.1 The Swedish Energy Market

Prior to 1996 the Swedish Energy Market was regulated, meaning that end consumers were forced to purchase electrical energy from the local energy distributor. The energy distributor had monopoly over a certain area, entailing that end consumers in no way could affect the electricity price (Ahlström, 2005). Since January 1996, however, the energy market in Sweden is deregulated in hopes of providing end consumers with more choices as well as to achieve more efficient and dynamic pricing. The deregulation of the energy market aimed to increase the possibilities for import and export of energy, meaning that companies could purchase and sell energy across the Swedish border. The energy price is since then allowed to fluctuate according to demand and supply (Ahlström, 2005).

##### 3.1.1 Energy Sources and Usage

There are many different areas where electricity has a significant role and the electricity usage between these areas varies greatly. Examples of different electricity utilizers are households (e.g heating, lightning, utilities), heavy industries (e.g chemical- steel- paper-industry), production sights (e.g heating, refrigerating, manufacturing) and transport (mainly rail-bound). The main electricity sources in Sweden are nuclear power plants, conventional thermal power stations (condensing power stations, combined heat and power (CHP)) and hydroelectric power (water) (Energimyndigheten, 2016b). *Figure 5* presents Sweden's total energy supply and its sources for year 2015 (Ekonomifakta, 2017). As it can be seen in *Figure 5* the total Swedish energy supply in 2015 was 525TWh and the most important energy types were nuclear energy, hydro power, biofuels and oil.

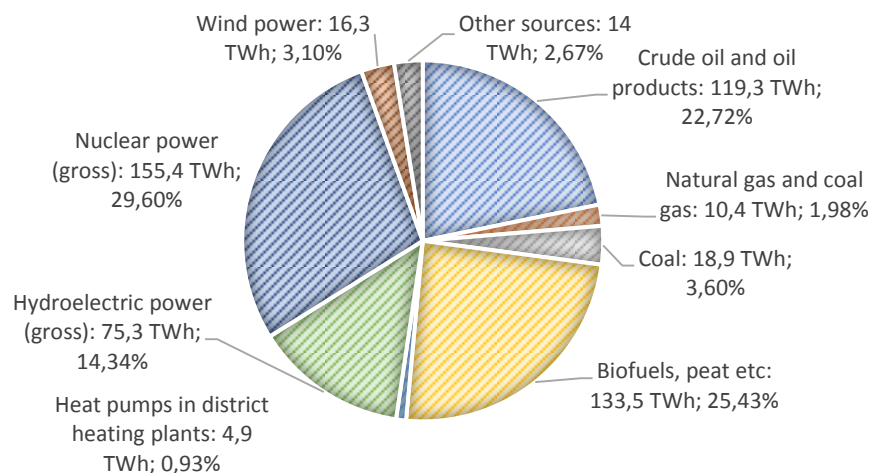


Figure 5. Sweden's main energy sources.

Hydroelectric power has the lowest variable cost and is often used as primary production and as a regulator in energy systems. The hydroelectric plants' water reservoirs are filled up during summer and emptied during the winter periods. Most hydroelectric power plants in Sweden are located in the northern part of the country. Nuclear energy has the second lowest variable cost and is used as primary production for as long as possible during the year, but mainly during autumn, winter and spring. Most nuclear power plants in Sweden are located in the middle and the southern part of the country (Ahlström, 2005).

The biggest electricity utilization in Sweden comes from the industry sector as well as the household- and service sector. In Sweden the electricity usage per person and year is relatively high which is because of the country's Northern position with cold winters and because of the country's heavy prime industry (Lindholm, 2017). According to Lindholm (2017) the average use of electricity per inhabitant and year in Sweden was 15 000 kWh during 2016. During the majority of the year Sweden's climate is cold which requires buildings and households to be heated. For the residential sector, there are four main ways to heat buildings; with direct electricity, district heating, boilers or heat pumps (Vattenfall, 2016). Below is a short description of each heating type:

### **Direct Electricity**

With direct electricity, energy is distributed in the house through pipes and radiators or floor heating. The main advantages with direct electricity are low investment costs, low energy losses and the simplicity for control. The disadvantages include relatively high operating costs and less flexibility to switch to other energy sources. (Vattenfall, 2016).

### **District Heating**

District heating is produced in a large, joint facility and is coupled to the building's heating system through a heat exchanger. The advantages with district heating are safe operation, a small environmental footprint and little maintenance. The main disadvantage is that district heating is not available everywhere (Vattenfall, 2016).

### **Boilers**

Water is heated in a boiler and heat is distributed through a waterborne radiator system. There are different types of boilers ranging from oil boilers to wood boilers and combination boilers (which use electricity, biofuels, oil). The overall advantage of using a boiler is high reliability. A disadvantage however is that operating costs are high (Vattenfall, 2016).

### **Heat Pumps**

Heat pumps allow for utilization of heat from air, water, soil or rocks. The pump is driven by electricity; however, it releases more energy than it consumes. There are different types of heat pumps (e.g geothermal heat pumps, air pumps and water pumps) and the selection of pump depends on the customer's need for heating and hot water, the current heating system in the building and the building's ventilation system (Vattenfall, 2016).

### 3.1.2 Electricity Market Players

Electrical energy is distributed from a large group of producers to consumers through a common power system, which is organized in a hierarchical structure, as illustrated in *Figure 6* (Söder & Amelin, *Efficient Operation and Planning of Power Systems*, 2011). The purpose of transmission grids is to transfer large amounts of energy across long distances. Sub-transmission grids, which make up the second level, serve as a link between the transmission grid and the distribution grid. The transferred energy is normally less on the sub-transmission grid compared to transmission grids and the transfer distances are shorter. The final level in the system is the distribution grid, which stretches all the way to the final consumer and distributes low voltage energy which is found in regular wall sockets (Söder & Amelin, *Efficient Operation and Planning of Power Systems*, 2011).

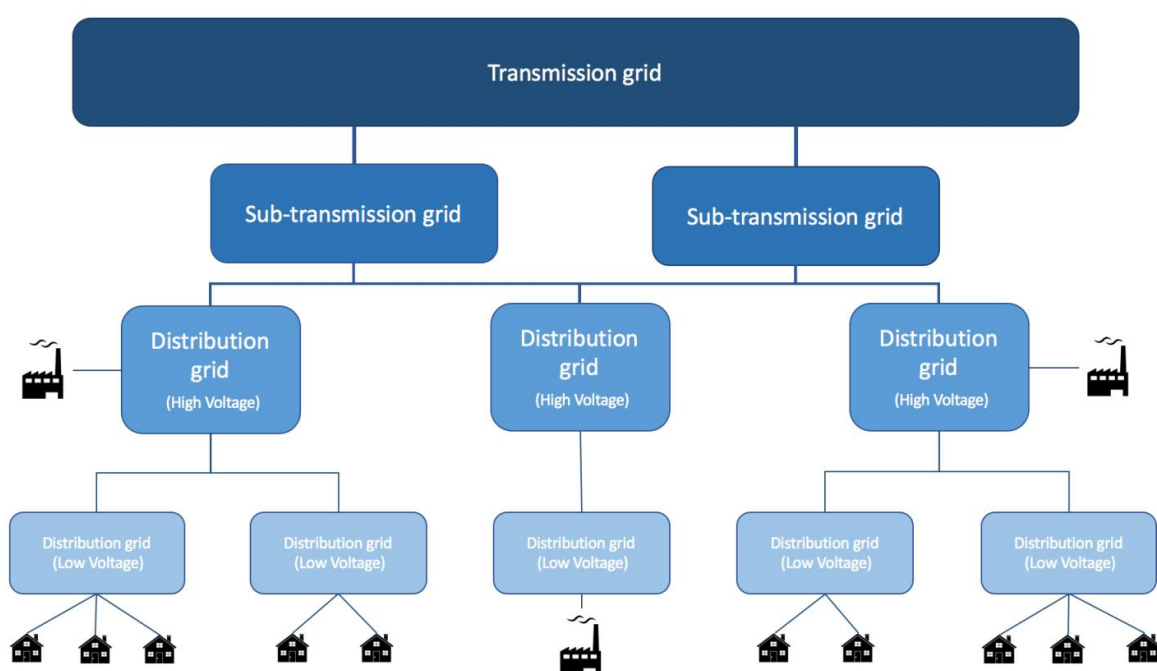


Figure 6. *Illustration of the hierarchical structure of the grid network in Sweden.*

In order to further understand the electricity market an insight to the different actors, their responsibilities and energy trading is needed. Below, each actor is described in more detail.

#### **Producers and Consumers**

Producers are the players which own and operate power plants in the electricity market. The producers sell their generated energy to either retailers, the electricity exchange market (NordPool) or directly to end consumer (Ahlström, 2005). In Sweden, the largest producers are; Vattenfall (state owned), Fortum Sverige, E.ON Sverige, Statkraft Sverige and Skellefteåkraft. The government stands for approximately 39% of the installed electricity generation capacity while foreign owners stand for about 39%, municipally owned companies account for 12% and other owners constitute the remaining 10% (Swedish Smart Grid,

2017a). Consumers are the players who are final users of the electrical energy that is being transferred through the grid. Both producers and consumers must pay fees to the grid owners in order to stay connected to the grid (Ahlström, 2005).

### **Grid Owners and System Operator**

The grid owner is the actor who delivers electricity and is responsible for the transportation of energy from the production plant to the user. If electrical losses occur, the grid owner may have to purchase electricity in order to cover the losses. The costs of these tasks are covered by grid tariffs for all users. The grid tariffs consist of a power part and an energy part. The energy part corresponds to variable costs i.e. primarily electrical losses. The power part corresponds to fixed costs for building and maintaining the grid, primarily depending on grid users' power output (Söder & Amelin, Efficient Operation and Planning of Power Systems, 2011). The three largest grid owners in Sweden are Ellevio, E.ON and Vattenfall, together they supply more than half of Sweden's electricity consumers with electricity. Many grid companies are also owned by municipalities (IVA Electricity Crossroads project, 2017). The system operator is the player who maintains safe operation of the power system and who administrates the electricity trading. The system operator has two main responsibilities, namely maintaining frequency control and managing post trading (Söder & Amelin, Efficient Operation and Planning of Power Systems, 2011). In Sweden, the system operator is Svenska Kraftnät (Svenska Kraftnät, 2016a).

### **Retailers and Balance Responsibility**

Retailers purchase electricity directly from producers or the power exchange and resell it to consumers, serving as a link between producers and consumers. Examples of Swedish electricity retailers are GodEl, DinEl, Luleå Energi, Tibro Energi and Bixia (Svenskt Kvalitetsindex, 2014). An energy supplier must, according to the Electricity Act, supply as much electricity as its customers consume (Svenska Kraftnät, 2016b). Any deviation is corrected in economic terms by the balance responsible player (Söder & Amelin, Efficient Operation and Planning of Power Systems, 2011). An energy supplier who has caused imbalance for the energy system is economically charged by Svenska Kraftnät for the cost of restoring balance. The cost is calculated in a balance settlement (Svenska Kraftnät, 2016b).

#### **3.1.3 Electricity Trading**

A functioning electricity trade means that producers get paid for the energy they generate and that consumers pay for the energy they consume. *Figure 7* illustrates how the different actors of the energy market in Sweden interact and how electricity trading is conducted (Söder & Amelin, Efficient Operation and Planning of Power Systems, 2011). Since an automatic control system operates the power system, the payment between electricity traders cannot happen in real-time. That is why *trading periods* exist, where the most common trading period is one hour (Söder & Amelin, Efficient Operation and Planning of Power Systems, 2011). As no players on the electricity market know exactly how much electricity that will be traded during a certain period, the trading action is divided into three steps:



**Ahead trading:** Before a trading period, players buy and sell as much energy as they think they need. There are different agreements that the players can make amongst each other: long-term contracts or short-term contracts. Long-term contracts are valid for multiple trading periods whereas short-term contracts apply to a single trading period. The advantage of using long-term contracts is that the players can gain favourable prices while the advantage of using short-term contracts is that they can adapt to prevailing circumstances (Söder & Amelin, Efficient Operation and Planning of Power Systems, 2011). Nord Pool Spot AS is the electricity market in the Nordics, which organizes electricity trading for the physical supply also known as “the spot market”. The spot market is mainly for short-term trading, and the trading there is done in physical electrical power or physical electricity contracts (Svenska Kraftnät, 2016a).

**Real-time trading:** During the actual trading period the system operator maintains the momentary balance between generation and consumption, in order to maintain safe operation of the power system. The power system’s instantaneous balance is measured by the frequency of the voltage, the frequency of the Nordic electricity system should be 50 Hz. To maintain balance between generation and consumption the system operator may have to steer the generation or consumption which is possible through real-time trading. In a real-time balancing market the system operator can induce a certain player to change its generation or consumption, by activating bids (down-regulation and up-regulation) that have been submitted to the real-time balancing market (Söder & Amelin, Efficient Operation and Planning of Power Systems, 2011).

**Post trading:** When a trading period has ended any deviations between the planned generation/consumption and the actual generation/consumption are adjusted. After the trading period the system operator compiles how much the balance responsible and its clients have actually produced/consumed and how much they have bought or sold in the ahead and real-time markets. To achieve balance after the trading period all balance responsible players have to trade in the post market (Söder & Amelin, Efficient Operation and Planning of Power Systems, 2011).

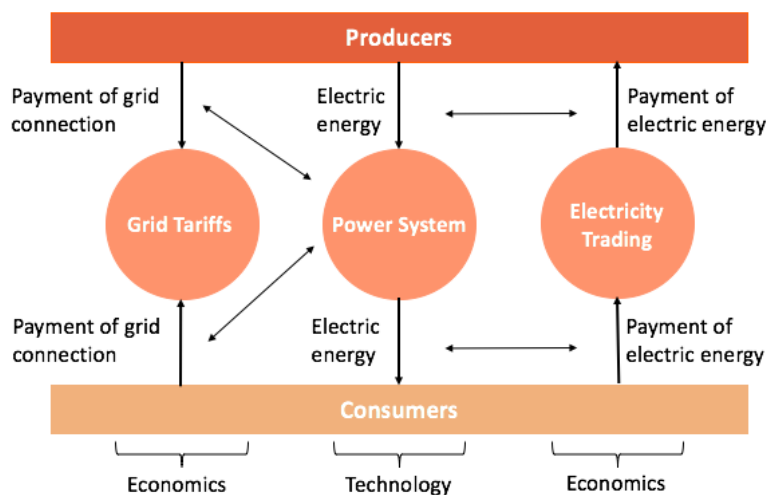


Figure 7. Illustration of the Swedish energy market structure

### 3.1.4 Agencies

Two important Energy agencies in Sweden are Energimarknadsinspektionen (Ei) and Energimyndigheten. Ei is a regulatory agency which works on behalf of the government. Ei monitor and analyse the energy market and its players. For example, the agency regulates the grid tariffs and monitor the revenue cap that is set for grid owners. They provide information to consumers and, for example, run the web service elpriskollen.se where customers can compare electricity prices and agreements of all dealers on the market (Energimarknadsinspektionen, 2017).

Energimyndigheten, on the other hand, is Sweden's Energy Agency which works to create conditions for efficient and sustainable energy use and cost-effective energy supply in many different sectors in society. Among other things, Energimyndigheten develops and spreads knowledge about efficient energy use which households, companies and governments can share. The agency also participates in international cooperation's in order to achieve climate- and renewable energy-goals, as well as work with supporting technologies, such as smart power grids and future vehicles, in their development. The agency also handles certain control instruments such as electricity certificates and emission trading, and they provide analyses, forecasts and statistics (Energimyndigheten, 2017).

There also exist other authorities which are active in the electricity market, such as Els akerhetsverket and Konkurrensverket. Els akerhetsverket is the authority responsible for technical safety issues, such as electrical safety. They issue regulations on the affected areas and, in other respects, are responsible for the supervision of electrical installations. Konkurrensverket are responsible of promoting effective competition and monitoring market competition, including the electricity market (Regeringskansliet, 2017a).

### 3.1.5 Regulations on the Electricity Market

There are many regulations incorporated in the energy market. Ewing (2012) mentions that two popular regulation methods are the revenue cap and the price cap, which are two very similar regulations. Lantz (2003) explains how both regulation methods entail that the regulator sets a limit for how much the regulating player is allowed to charge for its products. The price cap or revenue cap is often limited for an aggregated volume of products together, giving the regulated player room to elaborate with specific product prices freely, as long as the total revenues remain within the cap. According to Ei (2015b) the revenue cap regulates how much grid companies are allowed to charge their customers' in fees. The fees shall always be fair, objective and non-discriminatory according to the act. The revenue frame is governed in advance and applied for four years at a time. The purpose of setting the revenue frame in advance is to ensure that customers pay a fair price to the grid company and that they are provided with long-term delivery security, as well as an ensured Swedish electricity supply. Pre-regulation also helps the grid companies to achieve stable and long-term conditions for their grid business (Energimarknadsinspektionen, 2015b).

Svensk Energi (2015) published an article in which the author argued that the revenue cap for grid companies challenges the future development of the electric grid. The article explains how the Swedish grid system is facing the need for large investments for the future grid network and that the corporate responsibility of grid owners goes beyond service and fair prices towards customers. Maintenance of the grid is required, aging networks need replacing and should be expanded according to user needs. Svensk Energi (2015) mean that the entire energy system is facing a shift in which the development of the network is a key activity which requires room for investment.

As previously mentioned, the revenue cap is set in advance for a four year period. For the period of 2012-2015 the companies were given a decision on their revenue framework by the end of 2011 (Svensk Energi, 2015). What happened after that was that the majority of companies experienced that Ei had not applied the revenue cap-law in a reasonable manner, setting the revenue cap to low. Thus, the grid companies appealed against the decision. It was a process that went on until year 2015 and ended with grid companies getting right in all addressed areas - in three different courts (Svensk Energi, 2015). In their appeal, Fortum described how the set revenue cap was too low, hindering Fortum from developing and investing in essential refurbishments of the grid which are needed when integrating more renewable energy production into the energy system (Fortum Distribution AB, Fövaltningsrätten, 2012). All companies that appealed against Ei's revenue cap decision in 2011 were approved (Svensk Energi, 2015).

## 3.2 Challenges for the Swedish Energy System

The Swedish government has set the vision of having a sustainable and resource efficient energy supply as well as zero net emissions of greenhouse gases by 2050. However, many uncertainties and challenges exist which are connected to the future energy system, which must be overcome (Energimyndigheten, 2016c). The Swedish energy politics have three main goals which promote the 2050 fossil free vision – environmental sustainability, economic competitiveness and energy security (Tillväxtanalys, 2014). The goals for the energy- and climate politics will result in new demands for the energy system in order to restructure it to become more sustainable (Energimarknadsinspektionen, 2015c).

### 3.2.1 Integration of More Renewable Energy

In order to make the energy system more sustainable, and in order to reach the Swedish government's 2050 fossil fuel free goal, integration and balancing of more renewable energy sources, such as wind and solar power, is necessary (Energimarknadsinspektionen, 2015c). According to Svenska Kraftnät (2015) the development of renewable energy resources has been driven by the knowledge of carbon emissions from fossil fuels as well as the desire to be independent of importing energy from other countries. A challenge with renewable energy sources, is however that many of them are dependent on external conditions, such as weather. These variable sources are difficult to predict and therefore they create challenges for operation and reliability on of the grid (Svenska Kraftnät, 2015).

Energimyndigheten state in their report *Vägval och utmaningar för energisystemet* (2016c) that an increase of renewable energy will make it more difficult to balance the production and demand for energy, which must always be equal. Today the balance is maintained due to the electrical market, forecasting as well as flexible power resources. However, with more variable renewable sources, the uncertainty will increase and the demand for more advanced and accurate forecasting tools will arise (Energimyndigheten, 2016c).

The North European Power Perspective (NEPP) discuss in their report *Beskrivning av de konkreta utmaningar som det svenska elnätet står inför med anledning av den pågående omställningen av energisystemet* (2013b) how maintaining the continuous balance of production and demand will be a significant challenge when restructuring the energy system. NEPP further present two challenges that need to be solved. Firstly, the system has to be dimensioned in such a way that high delivery performance is achieved during hours when demand for energy is high but the production of variable energy sources is low. Secondly, the system has to be dimensioned for when demand for electricity is low but production is high, in order for prices not to collapse or for production no to go to waste. Using the current resources optimally, as well as dimensioning the system, will be a large challenge for the actors on the electricity market (North European Power Perspectives, 2013b).

Svenska Kraftnät (SVK) present in their report *Anpassning av energisystemet med en stor andel förnybar produktion* (2015) the consequences of more installed renewable sources both on the power system as a whole, but also for operation and delivery performance. SVK state how the cost of variable renewable sources is close to zero, resulting in decreased prices on the electricity market and therefore decreased profitability for all actors. Furthermore, the variability and uncertainty of renewable energy sources demands flexibility and accurate forecasting methods in order to maintain balance. As the energy sources are dependent on external factors, such as weather conditions, changes in consumption patterns due to fluctuations in temperature or weather can cause challenges for balance maintenance (Svenska Kraftnät, 2015).

The International Energy Agency (IEA) describe in their report *System integration of renewables: Implications for energy security* (2016a) how the increase of renewable energy in the energy mix is a paradigm shift for energy security. Fossil fuels, and a fossil fuel dominant energy market, entails risks such as geopolitical risks, upstream investments and infrastructure. However, renewable energy sources entail risks associated with availability as well as variability (IEA, System Integration of Renewables: Implications for Electricity Security, 2016a).

In order to integrate more renewable energy into the energy system, and thereby alter the current relation between fossil fuels and renewable sources, the IEA (2016b) presents two factors which are deemed to be critical and that need to be addressed. Firstly, variable renewable energy sources have constraints, such as sun hours and weather conditions. Furthermore, variable renewable energy is connected to the grid using power converter technologies, which differ from the traditional conventional generators, presenting a

challenge for integration. Secondly, the flexibility of the power system where the renewable energy is to be integrated has certain characteristics for demand and climate. A challenge for the power system is to be able to respond to swings in the supply and demand balance (IEA, Next Generation Wind and Solar Power, 2016b).

### 3.2.2 Uneven Load and Peak Demand

According to Ei's report *Incitament för effektivt utnyttjande av elnätet* (2015a) effective use of the electrical grid can be achieved by evening out the load and shaving peaks in demand. By evening out peaks the capacity on the grid can increase which opens up opportunities for connecting more renewable sources or customers without having to make large investments (Energimarknadsinspektionen, 2015a). According to Svenska Kraftnät the delivery performance of today's power systems is built on the fact that the market generates enough capacity in order to meet the highest peaks in demand. Pricing signals on the different markets act as an indicator for capacity shortages, i.e. not being able to meet the consumer's expected electrical usage (Svenska Kraftnät, 2015).

Energimyndigheten state in their report *Anpassning av elnäten till ett uthålligt energisystem - smarta mätare och intelligenta nät* (2010) that when determining the capacity of aerial lines, transformers or production units, it is the maximum power that is to be transported through the components that is the critical factor. Components are designed to be able to transport a certain amount of electrical energy. The amount is determined by the highest operating temperature that is allowed, which in turn is determined by the current size, surrounding temperature and the currents waveform. The purpose of the components is to transport electrical energy; the more energy it can transport, the better it fulfils its purpose. Being able to reduce peaks in power results in a decreased need to replace aerial lines, cables, transformers and production units (Energimyndigheten, 2010).

Ei further state in the report how a challenge is to even out the electrical consumption in order to utilize the grid and its components as effectively as possible. If consumption were to be evened out, and peaks reduced, the demand for new transmission lines and production units would be decreased (Energimyndigheten, 2010).

### 3.2.3 Transmission Losses

The difference between how much electricity that is fed into the grid and how much electricity that can be utilized is defined as transmission losses. Losses can be divided into two types, technical losses and non-technical losses. Technical losses can be either current dependent losses in transmission or non-current dependent losses. The current-dependent losses are square proportional to the current, seen to volume. Non-technical losses can consist of energy used for optimal function of the grid, illegal connections, energy extractions where meters are missing or wrongfully charged energy consumption due to metering issues (Energimarknadsinspektionen, 2015a).

According to Coelho & Neto et al. (2013) electrical losses are important in planning studies as they have a large impact on the cost matrix of distribution systems. The management model, which is often used by utilities, focuses on productivity and profitability, meaning that costs can be reduced by improving system performance. Regulatory agencies and utilities strive towards improving system efficiency and goals, as well as reduce technical losses. Therefore, there is an optimal level for technical losses which occurs when there are no additional investments that are economically justified (Coelho, A.C, & Neto, 2013).

### 3.3 European Initiatives for Sustainable Power Distribution

The European Commission have set a series of targets for achieving sustainable growth. By 2020 their aim is to reduce greenhouse gas emissions by 20% compared to the 1990 levels, increase energy efficiency by 20% and source 20% of energy from renewable sources. The European Commission present four main reasons as for why sustainable energy growth is necessary, namely fossil fuel dependence, strains on natural resources, climate change and competitiveness (European Commission, 2012).

The European Commission has a significant initiative for sustainable growth, namely “Resource-efficient Europe”. The Energy Union strategy consists of five dimensions which through cooperation and interaction aim to make energy more secure, affordable and sustainable. The first dimension aims towards creating security, solidarity and trust, focusing on cooperation between the EU member states (European Commission, 2017a). Integrating the European electricity markets and increasing the amount of renewable energy in the system will require that new transmission connections are created between countries. The European commission has pointed out the importance of strengthening the European electricity infrastructure and the interdisciplinary project Pathways to Sustainable European Energy System shares this vision. The research within the Pathways projects indicated that it is profitable for the European power system to increase the transmission connections between the member countries (North European Power Perspectives, 2011).

Interconnected grids would enable EU to boost its security of electricity supply and to integrate more renewable energy and avoid bottlenecks. For example, if a power plant fails or the energy supply fails to meet the demand during extreme weather conditions, it is essential that EU countries can rely on their neighbours for import of needed electricity (European Commission, 2017b). That is why the European Commission have set a goal of 15% electricity interconnection by 2030, meaning that all EU countries should have electricity cables in place which allow at least 10% of the electricity produced by their power plants to be transferred across borders to neighbouring countries (European Commission, 2017b). This also goes under the second dimension of the EU policies, namely integrating the internal energy market. Energy should be able to flow free through the EU adequate infrastructure, allowing for an efficient way to secure energy supply (European Commission, 2017a).

The third dimension of the energy policy is energy efficiency, which if it can be increased can reduce energy import dependence, reduce emission and promote growth (European

Commission, 2017a). Authors Nielsen & Haffner et al. (2013) state in their report that energy efficiency is attractive to policymakers for multiple reasons. Energy efficiency contributes to achieving environmental policy objectives as it impacts the consumption of fossil fuels and their negative environmental effects. Energy efficiency also often entails saving energy and money, which results in both macro and microeconomic benefits. On a micro level, awareness regarding energy issues are highlighted, household incomes are affected and vulnerability due to variation in energy prices are reduced. On a macro level the competitiveness is increased and peaks in energy prices are reduced (Nielsen, Haffner, & Ozbugday, 2013).

The final two dimension include decarbonizing the economy as well as research, innovation and competitiveness (European Commission, 2017a). Another measure taken by EU to achieve climate and energy goals is the introduction of a policy that will transform the entire energy system and how energy is sourced and produced, how energy is transported and how it is traded. The EU argues that we must find ways to make low-carbon technologies affordable and competitive, and to find these ways the EU have assigned the European Strategic Energy Technology Plan (SET-plan) (ETP SG, 2013). The SET-plan has created several platforms, namely the European Technology and Innovation Platforms (ETIPs) to create and support implementations of the SET-plan. One of the ETIPs, namely the Smart Networks for Energy Transition (SNET), has set out a vision for research and innovation for smart networks, storage and integrated systems. It will also identify innovation barriers, notably related to regulation and financing (ETIP SNET, 2016).

The European Union (EU) have also presented a package regarding how to keep the EU competitive with the clean energy transition in the global market, namely the Clean Energy for Consumers package. The package states that the EU want to lead the clean energy transition, as opposed to just adapting to it (European Commission, 2016a). SVK have identified a few trends from the Clean Energy for Consumers Package, namely; an increased centralization, regionalization of power and harmonization of regulations, more power to consumers and a strengthened role for regional and local grid networks, faith towards market solutions as well as transparency and equality (Svenska Kraftnät, 2017a). The EU describe how the package has three main goals; prioritizing energy efficiency, achieving global leadership in renewable energies and providing fair deals for consumers (European Commission, 2016a). For the Swedish electricity market this package confirms the current market model, creates opportunities for demand side flexibility, balance responsibility is strengthened and better resolution regarding time is achieved (Svenska Kraftnät, 2017a).

### 3.4 Demand Flexibility and Tariffs

According to Ei's report *Åtgärder för ökad efterfrågefleksibilitet i det svenska elsystemet* (Energimarknadsinspektionen, 2016a) many of the future challenges that will emerge as a result of increased levels of variable electricity production, in form of wind and solar power, correspond to frequency maintenance, power shortages, inefficient resource use and local grid problems. Handling these challenges will require utilization of all flexible resources in

the electrical system, i.e. flexible production, storage and demand flexibility. Ei explains that demand flexibility focuses on how electricity users can change their electricity consumption based on different signals. An example would be how customers decrease their electricity consumption when the grid is heavily charged, or how customers increase their electricity usage when the electricity price is low which, for example, occurs when the access to renewable energy generation is high.

Figure 8 describes how demand side flexibility leads to better balance of power on the grid during one day. As can be seen in Figure 8, demand side flexibility can lead to a more optimized and even energy consumption (The Northwest Power and Conservation Council, 2016). Ei mean that demand side flexibility can be part of the solution for future challenges and therefore it will become increasingly important to take advantage of customers' ability to be flexible in their electricity usage (Energimarknadsinspektionen, 2016a).

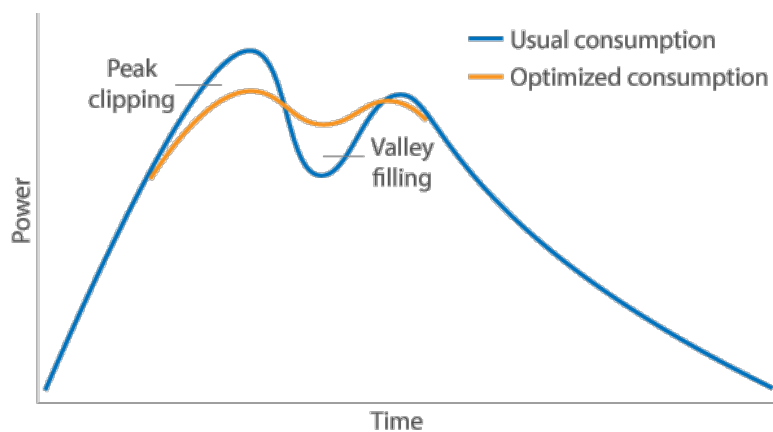


Figure 8. Illustration of the effect of demand side flexibility on the power output from the grid during

Ei (Energimarknadsinspektionen, 2016a) argues that demand flexibility is desirable for many reasons. For one, flexible demand can be adapted to available production and thus reduce the risk of power shortage. It can also reduce the need to reinvest in power plants and power grids to ensure the electricity requirements in peak load situations. Noth European Power Perspectives (NEPP) (2013a) argues that there are challenges that must be worked on in able to succeed with demand flexibility initiatives. One such challenge is the lack of measuring with a sufficient time resolution, which means that customers cannot act on price signals. Another challenge is the lack of knowledge and feedback around demand flexibility amongst customers. NEPP (2013a) mean that it is not easy to communicate with households about how demand flexibility works, relating to tariffs or risk distribution. In a study by Elforsk, *Att följa elpriset bättre* (2009), it was shown that knowledge, and thereby the increased control of electricity consumption, was an important driving force for households when choosing to participate in demand side flexibility programs or not.

In order to achieve increased demand flexibility, it is important to understand the driving forces behind customers becoming more flexible in their electricity usage. NEPP (2013a)



argue in their final report to Swedish Smart grid, that even if economic incentives are central driving forces, there are other factors that can affect customers as well. For example, household customers can feel that they take corporate social responsibility and contribute to environmental benefits by being flexible in their electricity consumption. It is also important that there are driving forces for operators in the electricity market to enable elderly people to use their potential for demand flexibility. Electricity market players may therefore need incentives or rules to achieve increased demand flexibility (Energimarknadsinspektionen, 2016a).

According to Ei (Energimarknadsinspektionen, 2016a), grid companies can provide incentives for customers to be flexible in their electricity usage through tariffs. Alvehag & Bartusch (2014) investigated the potential of residential demand flexibility programs in electricity distribution and found that, in short term, residential electricity consumers responded to price signals of a demand-based time-of-use electricity distribution tariff by shifting electricity consumption from peak demand hours to off-peak hours. The time-of-use tariffs are, unlike customary ones, based on peak demand and entail a unit price on the average of 3 to 5 highest instances of demand in peak hours respectively (Alvehag & Bartusch, 2014).

Today, the majority of electricity customers in Sweden have the amp-based tariff (in Swedish: “enkeltariffen”) with a fixed subscription fee, based on the customer’s amp size, and a variable fee (transfer fee) based on the electricity consumption (kWh) (Vattenfall, 2017a). In the future, customers will be given the opportunity to influence their electricity cost to a greater extent, and thus the incentives for demand flexibility will increase for the consumer. The potential for impact becomes significantly greater if today's fuse tariff, with a subscription fee based on the amp size, is replaced by a power tariff, with a fixed fee per month and a fee for utilized monthly power (Watne, 2017).

Watne (2017) argues that the future electricity landscape can evolve in different directions but that there are certain factors which, more or less, will affect grid owners’ revenues if the future tariff system has the same format as today. These factors, according to Watne, are:

**Electric vehicles**, which will increase the electricity usage and at the same time threaten the security of electrical supply, which means that the tariff will work as a tool to control incentives regarding power.

**Solar panels** in combination with energy storage, which entails that the transferred energy in the grid will decrease but the maximum power need will remain.

Watne (2017) further argues that a power tariff can be designed in a way so that incentives for load monitoring can increase by 10 times, compared to today’s time-based tariff. According to Vattenfall (2017b) the transition to power-based tariffs means that the fixed fee is divided into a power tariff and a fixed tariff. The share of the “transfer” tariff will remain unchanged; however it can be time differentiated or fixed over the whole year.

Figure 9 presents the difference between the current tariff structure and an example of a future tariff model (Vattenfall, 2017b).

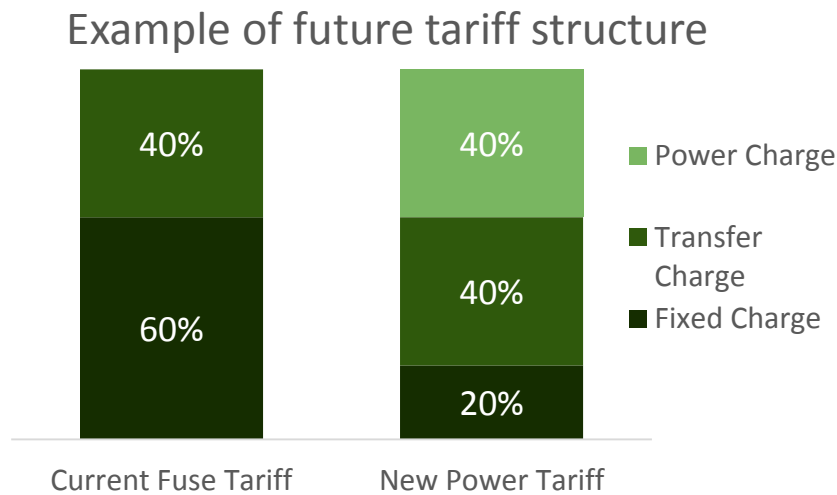


Figure 9. Example of a future tariff structure.

### 3.5 Decentralized Energy Management for Residential Buildings

The European Parliament present in their report *Decentralized Energy Systems* (2010) how the European energy system is moving towards becoming more decentralized, emphasizing more distributed generation, energy storage and more active involvement of customers through demand side flexibility. A paradigm shift from centralized control towards decentralized energy management is occurring, creating opportunities for devices that offer flexibility in their load profile (Van der Klauw, Gerards, & Hurink, 2017). According to Ei (2015d) small scale decentralized production is becoming more common in the European grids, and decentralization is advocated both on a European and national level. The development towards a more decentralized system, with more renewable energy sources and smart grids, increases the number of actors involved in the market as well as the use of IT, increasing the importance for information management (Energimyndigheten, 2015b).

The World Alliance for Decentralized Energy state that the terms distributed energy and decentralized energy often are used interchangeably. Distributed energy sometimes only refers to production whereas decentralized energy includes thermal power and electric energy (The World Alliance for Decentralized Energy, 2017). Distributed generation often includes efficient and low carbon technologies which are closer to the end user, and often smaller in scale, than traditional generation (Allan, Eromenko, Gilmarting, Kockar, & McGregor, 2015). Traditional electricity supply consists of a few large producers which are centrally controlled, with the goal of balancing production and consumption (Van der Klauw, Gerards, & Hurink, 2017). Decentralizing the electricity system is according to the authors Allan et al.

(2015) seen as mean for achieving renewable energy provision as well as for managing an aging electricity infrastructure and capacity constraints.

The European Parliament state that distributed energy resources consist of three main components; distributed generation, demand side flexibility and energy storage. The primary energy sources are often renewable; however fossil fuels also occur as the primary resource. Despite which energy source that is being used, a precondition is that it is available on a frequent and local basis. The demand flexibility component of distributed energy resources entails shifting loads in time, allowing for management of small end-users and deviations in supply. The energy storage component allows for storing energy when consumption is low and using it in the power system when demand is high or production is low (European Parliament , 2010).

According to author Sue et al. (2014) the supply-demand balance challenges that exist today, as well as development of new energy storage technologies, presents opportunities for distributed energy storage to be better deployed. The authors further emphasize how distributed energy storage comes in many different forms such as battery storage systems, energy management systems with controllable loads and emerging technologies, such as electric vehicles.

Authors Cardoso et al. (2014) state that the increased emergence of electric vehicles creates both challenges for distribution on the grid, but also possibilities for vehicle-to-grid services. If the volume of electric vehicles is large, then they could potentially work as a distributed energy resource as well as influence investments in other distributed energy technologies and applications, such as micro grids. According to Mendes et al. (2012) distributed energy technologies are seen as fundamental units of micro grids.

### 3.6 Theoretical Framework

The following section presents the theoretical framework used in the study. The terminologies disruptive innovation and value creation are presented as well as the chosen strategic analysis. The strategic analysis is created with the SWOT and PEST analysis as inspiration. Four main areas are put into focus and analysed from a *time, economics* and *relevance* perspective.

#### 3.6.1 Disruptive Innovation

In his book *The Innovator's Dilemma* (1997), Clayton Christensen, of Harvard Business School, explains the theory of disruptive innovation. He refers to the term when describing how innovations can create new markets by discovering new categories of customers. This is done by developing new business models for both old technologies that are used in new ways and for completely new technologies. Christensen (1997) explains that the difference between a disruptive innovation and a sustaining innovation is that the sustaining innovation improves existing products while a disruptive innovation can create new products for new markets.

According to Duening & Hisrich et al. (2015) disruptive innovations across numerous technology industries are changing the way people interact and live their lives. Some examples of the more powerful transformative internet technology trends in recent years include: Big Data, Collaborative Commerce, Cloud Computing and Internet of Things. There are two main views that define disruptive technologies, competence-based and market-based. The competence based view says that firms should make changes to their capabilities as a result of technological discontinuities (Anderson & Tushman, Technological Discontinuities and Dominant Designs: A Cyclical Model of Technological Change , 1990). The market based view on the other hand, alters the performance of a product from a customer's point of view (Markides, 2006).

According to Christensen (1997) disruptive technologies often fall short of a dominant technology on core production dimensions which customers value, underperforming during their initial release. However, disruptive technologies exceed capabilities on a few dimensions compared to dominant technologies, appealing to fringe customers. With time, the core product dimensions are improved and more customers find the technology appealing. Christensen argues how eventually the dominant technology is displaced by the disruptive technology, appealing to mainstream customers.

According to authors Shomalia & Pinkseb (2015) rethinking of business models is often derived from the emergence of disruptive technologies, however, not all firms are open to altering their business model. New entrants often do not have strong barriers to innovate their business model. The barriers for incumbents are often larger resulting in them integrating a new technology into their existing business model (Shomalia & Pinkseb, 2015)

Small innovative companies can compete with big players on the technology market as they can solve local issues which many global companies overlook (Christensen, 1997). Duening & Hisrich et al. (2015) discuss how recent technology innovations can be utilized in order to disrupt well established markets. The innovations of Big Data as well as Internet of Things (IoT), present opportunities allowing for transformation of traditional industries, both locally and globally.

### 3.6.2 Value Creation

Creating a business model for a start-up business is usually an iterative process. Using a business plan as a roadmap often fails, as both the product and the customers are unknown (Blank & Dorf, The Startup Owner's Manual – The Step-by-Step Guide for Building a Great Company, 2012). According to Duening & Hirsch et al. (2015) it is important to distinguish between a start-up and a large company. Start-ups initially do not have any customers and can therefore not directly apply a business model, as it may not succeed in delivering value to the targeted group. Therefore, creating revenue and sales is not always the main goal of start-ups in an initial stage, instead many businesses focus on building credibility or investigating customer demand (Duening, Hisrich, & Lechter, 2015).

Duening & Hirsch et al. (2015) state that it is the customers who determine what is valuable, where value is defined as what customers believe it to be. The authors further state how value creation requires vision, passion and the ability to adjust according to trends and customer needs.

The term *customer development* is presented by Steve Blank in his book *The four steps to the epiphany: Successful strategies for products that win* (2013) as a process for gaining customer insights through continuous feedback loops during a product's cycle of development. Author Ladd (2016) describe the phenomenon of customer development as a method for entrepreneurs to reduce risk and avoid costly mistakes through validating and rejecting hypothesis based on customer feedback. Author Marurya (2012) states that the key takeaway from customer development is how in order to succeed with customer development you must look outside and directly engage with customers. Customer development is also part of the core in the Lean Startup Method (Ladd, 2016).

Maurya (2012) describes the term Lean Startup as a synthesis of customer development, agile software development methodologies and lean. The lean start-up process is circular, iterative and experimental (Duening & Hisrich et al., 2015). It is a method for helping businesses validate or reject hypothesis in a manner that limits the wasteful activities (Frederiksen & Brem, 2017). Ideas are transformed into minimum viable products which are tested on customers, the process being iterative until a certain number of customers accept the product (Duening & Hisrich et al., 2015).

### 3.6.3 Strategic Analysis

When speaking about strategic analysis the definition often differs, however certain common factors exist which are associated with strategic analysis and these are according to the Chartered Institute of Management Accountants (CIMA, 2007):

- 1) Identification and evaluation of data relevant to make a strategy formulation
- 2) Defining the external and internal environment that is to be analysed
- 3) Several analytical methods can be employed in the analysis

Examples of two analytical tools that are commonly used in strategic analysis include:

- **SWOT analysis:** a tool which contributes with understanding of a project or business cases Strengths, Weaknesses, Opportunities and Threats (CIMA, 2007).
- **PEST analysis:** a scan of external macro-environments where the organization exists. PEST analysis is useful when wanting to understand the Political, Economical, Socio-cultural and Technological environment in which the organization operates. It can be used for evaluating market growth or decline, and thus also the position, potential and direction for a business. (CIMA, 2007).

Based on the scope of this study, an analytics framework has been developed based on the basic concept of the SWOT- and PEST framework, with the basic concept being the analysis from different perspectives. The empirics for this study were gathered and structured according to four categories, see *Figure 10*, namely *Challenges*, *Future trends*, *Supporting factors for the DCB* and *Perceived risk and barriers for the DCB*. These categories were selected as they together form a broad overview of the area, which according to Blomqvist & Hallin (2015) is good way to understand the phenomena that is being studied. Furthermore, the categories together cover both *external* and *internal* environments to analyse, which is one of the main factors in strategic analysis (CIMA, 2007).

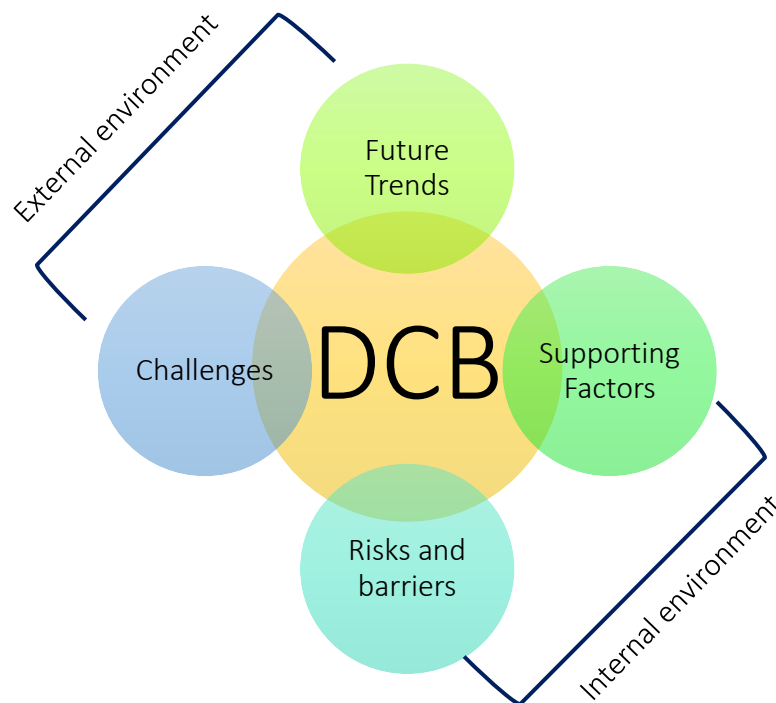


Figure 10. *Illustration of the four main categories for which empirical data has been gathered in order to study potential markets for the DCB.*

The empirical results were then analysed from three different dimensions; *relevance*, *time* and *economics*, according to *Figure 12*. These dimensions were applied for the he different market segments that were analysed, i.e. utilities, electric retailers, real estate companies and homeowners. By analysing data and information from different angles the triangulation of the study will improve as well as its relevance (Collins & Hussey, 2014). For each dimension there are classifications, *low*, *medium* and *high*. These classifications emphasize how important a certain market segment perceives each dimension. *Figure 11* presents an example of the framework when it is applied with regard to a specific actor, market, company or person who, in this example, values time and relevance highly, but economics low.

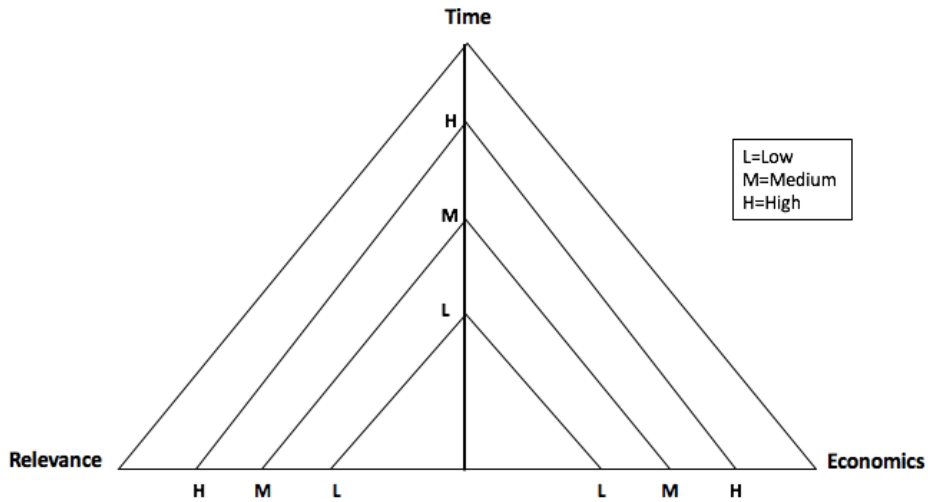


Figure 12. *Illustration of the framework used to analyze a certain phenomenon from a time-, relevance- and economical point of view.*

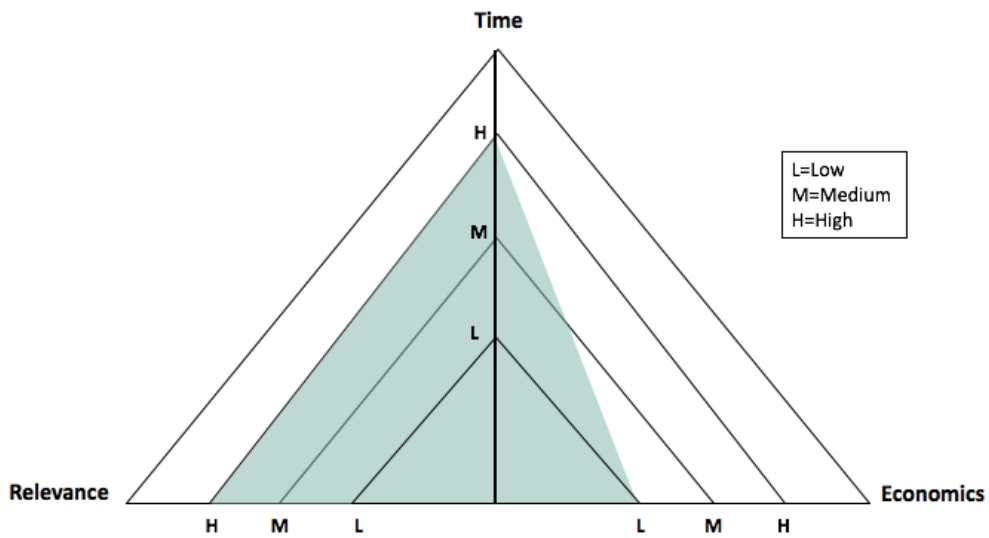


Figure 11. *The highlighted area shows that relevance and time are of high importance for this hypothetical actor and that economics is of low importance.*





## 4. Results

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*The following chapter presents a case study background for the DCB and the empirical findings from the conducted interviews. The case study background presents a more in depth explanation of what the DCB is and what the main hypothesis are around it, including why it is believed to be necessary from an energy market point of view. The empirical findings are presented in a structured manner, focusing on one stakeholder-segment at a time.*

### 4.1 Case study

The following section presents a background in form of a case study of the DCB in order to create a better understanding for the subject and why it is of importance to investigate. The traditional circuit breaker market, as well as smart energy services are presented as they are potential competitors to the DCB.

#### 4.1.1 Circuit Breakers

According to Schalabbach (2005) electric power systems have to be designed in a way that enable safe, reliable and economic supply of the load. Author Flurschein (1982) describes how the purpose of circuit breakers is to control electrical power networks by either carrying load, i.e. switching circuits on, or by switching circuits off. Time, reliability and safety are crucial attributes for circuit breakers (Schalabbach, 2005). When faulty circuits occur or short circuits are interrupted, the circuit breaker provides electric isolation and switches to an open position. As the switch of conditions (on and off) rarely occurs, circuit breakers have to be constructed to quickly and reliably switch positions, after having been fixed for a long period of time, in order to break the current (Flurschein, 1982).

Circuit breakers today are mechanical, meaning that the circuit breaking process is limited by the mechanical components. Author Sutherland (2014) describes how the breaking process is often divided into two parts, an initial trip signal and a contact parting. After the tripping signal and contact parting has occurred, no current can flow through the circuit and the voltage is then zero. Author Sutherland (2014) further emphasizes how standards and procedures determine how the circuit breakers are constructed, however, the common purpose of the standards is to protect people from hazards in homes, workplaces and other buildings where people reside.

According to authors Bakshi & Bakshi (2012) there are different criteria for classification of circuit breakers. These criteria include; operation medium, according to service, way of operation, action, method of control, way of mounting, tank construction and contacts. The DCB that is studied in this report corresponds to a digitized version of the traditional low voltage miniature circuit breaker (MCB). The traditional MCB is mainly used in domestic, light-industrial or commercial applications (Laughton & Warne, 2002). Examples of actors manufacturing MCBs that were identified during our market research were Schneider Electric, ABB, Eaton, Hager, Mitsubishi and Legrand. What was identified during the

market research was that none of the actors offered a completely digitized version of a MCB, however some actors have included smart elements in their breakers. Eaton, for example, have developed the Energy Management Circuit Breaker which offers circuit protection combined with internet connectivity and on-board intelligence, allowing for the circuit breaker to become smart and provide information for energy management (Eaton, 2016).

#### 4.1.2 Smart Energy Services

The growing consumer demand for tailored services that combine benefits, in terms of saving time and money, or improving quality of life is an important spur for the adoption of smart services (Accenture Digital, 2017). For example, utility providers which offer the ability to optimize energy efficiency, as opposed to just advising on the subject, will be more likely to be chosen by consumers. These types of utility companies will allow customers to save money and reduce their energy consumption, while at the same time decrease their carbon footprint (Accenture Digital, 2017). An example of such a company is Chai Energy, who work with an integrated energy management system which allows customers to control heating remotely via smartphones and which gives customized home analysis that can advise customers on how to lower their energy costs (Chai Energy, 2017). The rising demand for efficient energy management solutions for homes includes everything from more atomized home solutions, such as being able to remotely switch on lights or for heating to correspond with inhabitants living patterns, to smart alarms that allows for remote security monitoring (Accenture Digital, 2017).

Accenture Digital (2017) emphasize that there also exists a potential for making entire buildings more efficient. Today, environmentally unsound buildings collectively have a huge impact on the air quality in cities. However, by using sensors that collect data, in real time, about building's energy efficiency or carbon emission the environmental impact of building can be reduced. With the help of sensors or other smart technology that can be embedded into buildings, air-conditioning units, water pipes, heating and security systems or lightning, valuable data can be delivered to landlords of each individual buildings behaviour. By providing landlords with this kind of data, crucial repairs can be anticipated, the comfort of occupants can be seen too and energy costs can be lowered (Accenture Digital, 2017).

The premium electric car manufacturer Tesla, have developed an in-car app named the Smartcar, which supports drivers in reducing their electricity bills by optimizing energy use while driving as well as avoiding peak hour-rates when recharging. Today, modern utilities and grid operators are utilizing battery technology like never before (Accenture Digital, 2017). Tesla is also touching upon the potential of energy storage by putting together thousands of batteries to form an energy network which utility companies can use to deliver direct value for the electrical system. Tesla can today bundle Powerwall and Powerpack batteries into what today is called aggregation, to help utilities with peak shaving and demand side flexibility (Tesla, 2017). Another company, working with smart demand flexibility tools is Enernoc (Enernoc, 2017). Consumers benefit from this both by always having a back-up

power source for their home, but also by receiving compensation for letting utilities use their batteries when the energy demand is high (Tesla, 2017).

#### 4.1.3 The Digital Circuit Breaker

The digital circuit breaker (DCB) is currently undergoing a development phase where the technology is being developed and perfected. As there are no similar products on the market today the DCB is, according to Manetos, a technology that will disrupt the traditional circuit breaker market and, depending on the chosen business model, the electricity market.

The distribution board, where circuit breakers are installed, is an intermediary between a building’s electrical appliances and the electrical grid. It is in the distribution board where Manetos see potential to create value and enable power control through digitalizing traditional MCBs, i.e. converting it to a digital circuit breaker (DCB). This digitalization allows for monitoring and remote control of all appliances in a building, better resolution of electricity usage data, faster current breaking and increased transparency into the buildings electricity consumption. The digitalization also enables a two-way communication with the grid. Based on this, there exist many hypotheses for which potential services, functions, value and business models the DCB can deliver. *Table 2* presents the main hypothesis associated with the DCB, including the potential business areas and markets, as well as their believed need for this type of solution. The hypotheses were created based on the information collected in the literature review.

Table 2. *Hypotheses associated with the DCB for each potential business market.*

<b>Actors</b>	<b>Challenges</b>	<b>Business Cases for the DCB</b>
<b>Electric utilities</b>	<ul style="list-style-type: none"> <li>• Peaks in demand are costly and cause strain the electric grid</li> </ul>	<ul style="list-style-type: none"> <li>• Enable peak shaving for grid companies by controlling customer load</li> </ul>
<b>Agencies</b>	<ul style="list-style-type: none"> <li>• Reaching environmental and climate goals</li> </ul>	<ul style="list-style-type: none"> <li>• Contribute to reaching set goals through more efficient use of electricity</li> </ul>
<b>Homeowners</b>	<ul style="list-style-type: none"> <li>• Little insight into their electricity consumption and low knowledge regarding energy hungry appliances</li> <li>• High electricity costs for homeowners with direct heating</li> </ul>	<ul style="list-style-type: none"> <li>• Provide better control and transparency for electricity consumption through DCBs</li> <li>• Provide solutions and recommendations for savings</li> </ul>
<b>Real Estate Owners</b>	<ul style="list-style-type: none"> <li>• Limited remote control and overview of buildings’ electricity consumption</li> <li>• Manual work required to identify abnormalities in energy consumption and faulty appliances</li> </ul>	<ul style="list-style-type: none"> <li>• Enable better overview and control of buildings’ energy consumption and appliances through DCBs</li> <li>• Reduce manual work - digitalized remote control</li> </ul>

## 4.2 Empirical Results

The following section presents the empirical findings for each investigated market segment as well as agencies and experts/researchers. The actors that have been investigated with corresponding results presented below are: *agencies, utilities, energy retailers, real estate companies, homeowners, experts and researchers*. Diagrams and charts will be used to better visualize the findings for each segment.

### 4.2.1 Agencies

The empirical material for agencies was collected through semi-structured interviews with Swedish Smartgrid and Energimarknadsinspektionen (Ei). An overview of each actors' opinion is presented in *Table 3*, followed by subchapters, which present the discussed topics in more detail, and diagrams, which present a better overview of the empirical findings.

Table 3. *Overview of agencies' opinions towards the DCB.*

	<b>Challenges for the Energy Market</b>	<b>Future Trends for the Energy Market</b>	<b>Supporting Factors for the DCB</b>	<b>Perceived Risks and Barriers for the DCB</b>
<b>Swedish Smartgrid</b>	<ul style="list-style-type: none"> <li>Managing an increased amount of intermittent energy</li> <li>Physical challenges and bottlenecks on all levels of the electricity market</li> <li>Shift in roles and responsibility</li> <li>Regulations</li> </ul>	<ul style="list-style-type: none"> <li>Shift in the role of grid owners</li> <li>More clean energy</li> <li>Consumers having a more central and active role</li> <li>Energy Communities</li> </ul>	<ul style="list-style-type: none"> <li>Socioeconomics</li> </ul>	<ul style="list-style-type: none"> <li>Personal data and contracts</li> <li>Product liability and responsibility</li> <li>Building a large user base</li> <li>Peak shaving not being a critical enough issue</li> </ul>
<b>Ei</b>	<ul style="list-style-type: none"> <li>Managing an increased amount of intermittent energy</li> <li>Regulations and responsibility for energy storage</li> <li>Inconsistent customer behaviour</li> <li>Transmission losses and high power output -from a regulation perspective</li> </ul>	<ul style="list-style-type: none"> <li>Increased amount of intermittent energy</li> <li>Demand side flexibility</li> <li>Increased amount of electric vehicles</li> <li>Energy Storage</li> </ul>	<ul style="list-style-type: none"> <li>Power-based and time differentiated tariffs</li> <li>Socioeconomics</li> <li>Solutions which harness volatile and unpredictable energy sources</li> <li>Demand side flexibility</li> </ul>	<ul style="list-style-type: none"> <li>Cyber security</li> <li>How to commercially justify the power control for homeowners and motivate margins</li> <li>Regulations for grid owners' costs associated to new technologies</li> </ul>

#### 4.2.1.1 Challenges for the Energy Market

Both representatives from Swedish Smartgrid and Energimarknadsinspektionen (Ei) shared the opinion that a challenge for the energy system is the increased amount of intermittent energy that is to be integrated, see *Figure 13*. As these energy sources are dependent on external factors, such as sun and wind, it is a challenge to guarantee that power can be delivered at all times. High demand or lack of production are examples of scenarios when difficulties in delivering power may occur. Ei's representative emphasized how Sweden has a large amount of hydro power which can help balance out the system when intermittent resources are fluctuating. A potential solution for integrating intermittent energy that Ei's representative discussed, was demand side flexibility, where focus is put on how households, in a large mass, can have a significant impact on the load of the electrical grid.

The representative from Swedish Smartgrid discussed how the integration of more intermittent energy entails a large physical challenge for all levels of the electrical system, both nationally, regionally and locally. These challenges, such as bottlenecks in the national grid, were described as challenges which are currently being worked. Swedish Smartgrid's representative pointed out how it is not only *how* the integration of renewables is performed that is of importance, but also *where* in the system that the integration is to take place.

Ei's representative presented another challenge associated with the integration of renewable and intermittent energy sources, namely creating and developing new technologies and solutions which facilitate the integration and which are commercially viable. Technologies such as new batteries are examples of solutions which can utilize volatile energy sources and act as energy storage. Even the trend of electric vehicles could be a mean for helping to balance the grid. It is, however, common that technologies in early stages are expensive, creating a barrier for adoption amongst customers. For Ei, this becomes a significant issue if grid owners can charge for different technologies through regulation of tariffs. Today standard rates exist which many people believe favour traditional technology. Ei's representative stated that for grid owners it often comes down to Ei's grid regulations, i.e. which new technologies that they can receive reimbursements for with current regulations. It is therefore the regulations surrounding how their funds are calculated, and other incentives that regulations entail, which makes new technology expensive. Another regulation includes if grid owners should be allowed to charge for pilot plants. For Ei, the actor being responsible for regulations, it is a challenge to create balance between not disfavours new and innovative technology and solutions, but at the same time having a socioeconomic perspective where business does not negatively impact the customers' tariffs.

Transmission losses on the grid, and the increase of losses that comes with variable load, is a challenge which was deemed important during the interview with Ei's representative. As transmission losses are exponentially dependant on the current, losses are larger if the distribution of energy is uneven as opposed to even, when extracting the same amount of total energy. At the same time, customer behaviour has become more unpredictable and technologies such as electrical vehicles present new challenges for the grid. Reducing power outputs and evening out peaks in demand, through for example demand side flexibility, can

according to Ei's representative potentially have an impact on the level of refurbishment required on the grid and can positively affect the environment.

During both interviews, challenges from a regulation and market perspective were also discussed. Swedish Smartgrid's representative emphasized the importance of the different actors on the market and their associated responsibilities. Extra focus was put on the monopoly actors (grid owners) and what their responsibilities should include. In Sweden the grid companies have natural monopolies and their markets are regulated and reviewed by Ei. In the future, if certain activities, services or functions, such as energy storage, were to fall under a monopoly actor's responsibility it would have consequences for competitive players within the same area. Therefore, roles and responsibilities are deemed to be a future challenge, which is something which falls under Ei's responsibility as it is they who take care of regulation and energy legislation in the Swedish energy market.

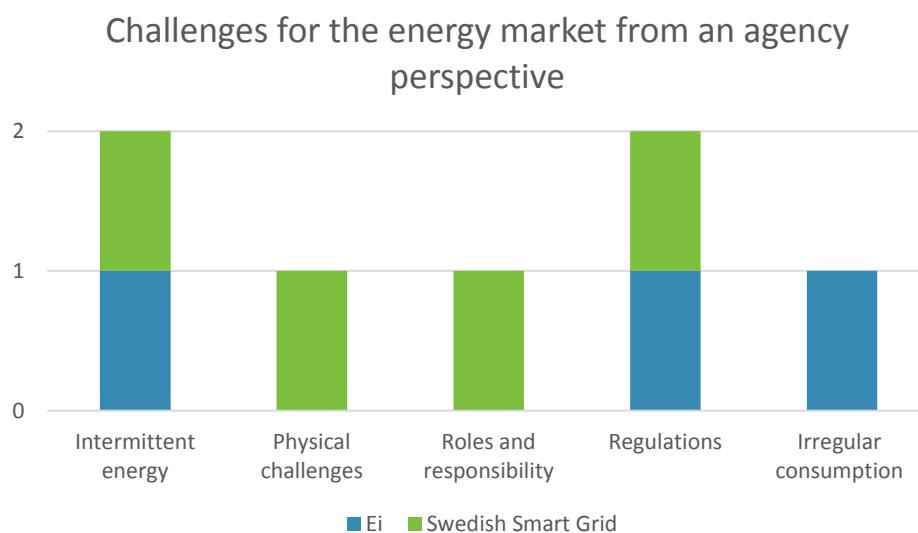


Figure 13. Summary of agencies' perception of challenges for the energy market.

#### 4.2.1.2 Future Trends for the Energy Market

Both representatives from Swedish Smartgrid and Ei shared the opinion that a future trend on the electricity market is that consumers, through various ways, will have a more active and central role, see *Figure 14*. The Ei representative spoke about how customer engagement through demand side flexibility could impact the electrical load, increase flexibility as well as increase security of supply for the grid. Swedish Smartgrid's representative presented the trend of Energy Communities, where energy consumers have an independent and active role. Consumers who have self-sufficient grids could potentially integrate themselves on the traditional electricity market and sell capacity. This entails challenges from a market perspective as well as how the communities should be integrated with the current grid. However, what both representatives had in common with this trend was that the role of energy consumers is going to develop and become more active in the future.

The Swedish Smartgrid representative also spoke about the shift in responsibilities of grid owners. A measure that may have a big impact on the future European electricity market is the EU commission’s Clean Energy for Consumers package, which includes market design, roles and responsibilities as well as information management. The package will impact countries legislations and is seen as a step towards creating a common energy union in Europe. There are however many different views on what the role and responsibilities of the grid owner should entail. One opinion is that the grid owner should have more responsibility than today, allowing them to own storage, as this is believed to be more socioeconomically efficient. Other opinions believe that each actor on the electricity market should work with their core competence and that competitive actors should take care of everything outside the core competences. Swedish Smartgrid’s representative means that these opinions are going to have to merge and that they together will create the new role of the grid owner.

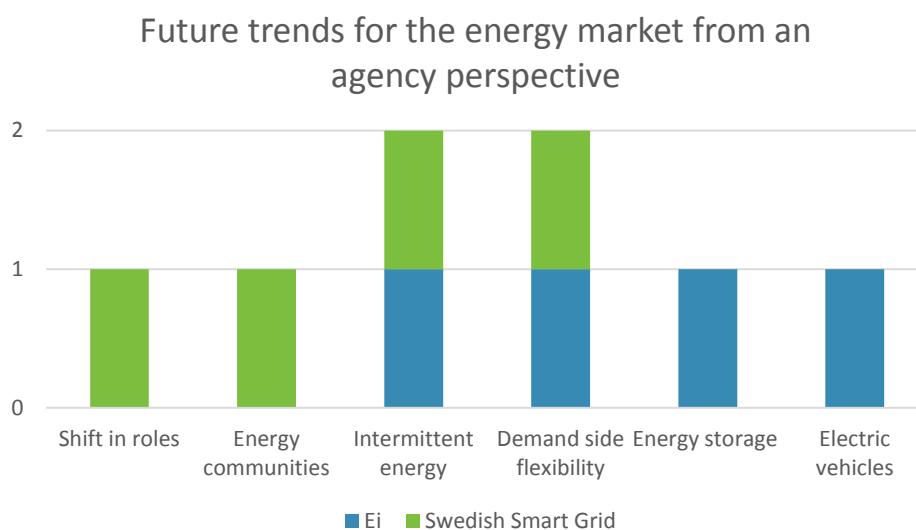


Figure 14. Summary of agencies’ perception of future trends for the energy market.

#### 4.2.1.3 Supporting factors for the DCB

According to both representatives from Swedish Smartgrid and Ei, socioeconomics plays an important role for the future energy system, see *Figure 15*. Being able to manage loads and shave peaks can create large savings not only for players on the electricity market but also for society as a whole. Ei’s representative pointed out how Energimyndigheten recently began offering support for energy storage solutions, since integrating more intermittent energy is an issue for the energy system.

The emergence and increase of power-based and time-differentiated tariffs, which according to the Ei representative are becoming more significant, could potentially act in favour of the DCB. New tariffs which use the maximum power as benchmark for the electricity price may become dominant in the future. If the tariff were to be based on the maximum power that is

consumed, then electricity prices may increase, creating incentives for controlling and managing electricity through the DCB.

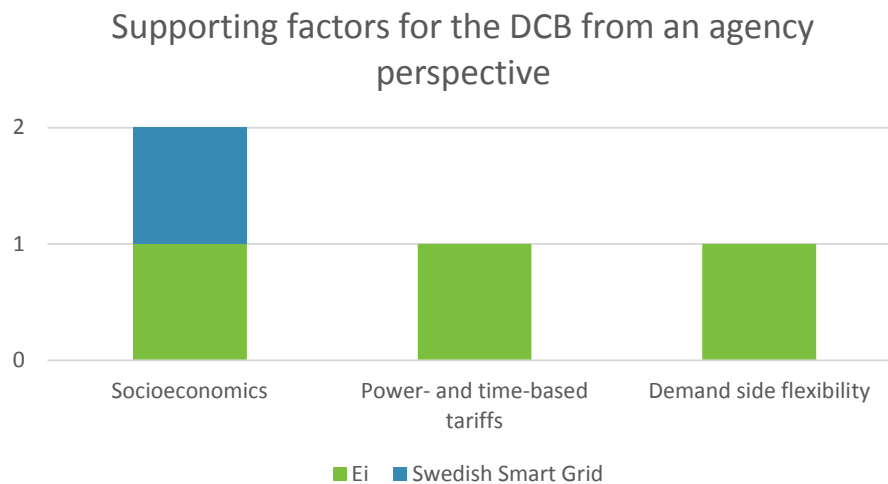


Figure 15. Summary of agencies' perception of supporting factors for the DCB.

#### 4.2.1.4 Perceived Risks and Barriers for the DCB

A common barrier for the DCB that both the representative from Ei and Swedish Smartgrid identified was how personal data and associated risks are to be handled, see *Figure 16*. Swedish Smartgrid's representative saw data integrity as a critical challenge. Today all data that is generated from a home's metering cabinet is classified as personal data and so it falls under the Swedish Personal Data Act (PUL). However, the rules between the metering cabinet and PUL are quite unclear. For example, if data collection can be used to profile customers (meaning that the data can be used to map people's daily life in aspects of when they are home/away, when they shower etc.) there needs to be some sort of agreement where the homeowner gives consent for this type of data collection. Therefore, Swedish Smartgrid's representative emphasized the importance of clear agreements and contracts with the homeowner. Furthermore, how collected data is stored and handled, as well as for how long it is stored, is also of importance. Having customers that do not know for how long their data is stored and what happens with it over time could potentially create a barrier for the DCB. The representative from Swedish Smartgrid pointed out that it often is not technology that is the issue, but rather who does what in the value chain, who has access to data, how data is used and how contracts between the actors are designed. The representative from Ei emphasized the importance of cybersecurity and data integrity in a similar way.

According to Ei's representative providing solutions between electrical grid companies and customers is often seen as positive. However, making the solutions commercially viable, in a large scale, often becomes a barrier. An important aspect is regulations for what business the grid owners are allowed to conduct. As they are a monopoly actor the business has to be separated from the competitive market. A potential suggestion for this could be having a third



party whom has contracts with customers which allows them to sell grid services to the grid owner.

The representative from Ei's view on the DCB solution was that it might be difficult for grid owners to make a profit from it. The perception of the DCB was that a large volume of end-users is required in order to have an impact on the electrical load through reallocation of electrical loads or peak shaving. In order to achieve a large volume, barriers such as motivating power control for homeowners and achieving high margins despite low electricity prices must be overcome. The representative also pointed out that new technology often is more expensive before becoming mainstream, which may become a barrier for building a large customer base.

Swedish Smartgrid's representative also pointed out how creating a large customer base can become a hinder for the DCB, see *Figure 16*. In order for the DCB to be accepted the representative believed that it must be cost-driven, meaning that margins have to be high in order for a customer to install it in their home. However, power peaks are not seen as a top priority issue according to Swedish Smartgrid's representative. For producers, power peaks become expensive entailing that the electricity price increases. For grid owners the peaks become an issue regarding power and capacity. Furthermore, the representative pointed out how product liability and responsibility can be a risk for the DCB as it is installed in customers' homes and it has control over their appliances. Her perception was that the DCB must be able to prove that it has not had a negative impact on an appliance if it were to break, otherwise the product responsibility might fall on the DCB.

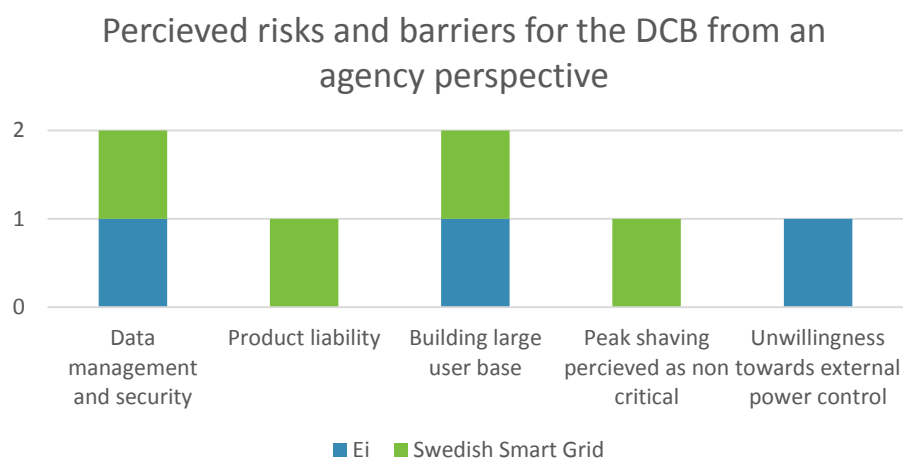


Figure 16. Summary of agencies' perception of risks and barriers for the DCB.

#### 4.2.2 Utilities

The following section presents an overview of electric utilities' opinion regarding challenges and trends for the energy system, see *Table 4*, as well as supporting factors and barriers for the DCB. The interviewed electric utilities consist of both electricity producers and distributors, as well as a mix of privately owned and municipally owned companies.

Table 4. Overview of electric utilities' opinions towards the DCB.

	<b>Challenges for the Energy Market</b>	<b>Future Trends for the Energy Market</b>	<b>Supporting factors for the DCB</b>	<b>Perceived Risk and Barriers for the DCB</b>
<b>Ellevio</b>	<ul style="list-style-type: none"> <li>• Aged and outdated grid infrastructure</li> <li>• Large investment costs for renewing power lines.</li> <li>• Managing an increased amount of intermittent energy</li> </ul>	<ul style="list-style-type: none"> <li>• Increased amount of electric vehicles</li> <li>• More locally produced energy</li> <li>• Smarter homes</li> <li>• Energy storage - batteries</li> <li>• End consumers potentially selling energy back to the grid</li> </ul>	<ul style="list-style-type: none"> <li>• Transition to power-based tariffs</li> </ul>	<ul style="list-style-type: none"> <li>• Low electricity prices entail little economic incentives for end-consumers to install the DCB</li> <li>• The data protection reform</li> <li>• Low willingness if user volume is low</li> </ul>
<b>Vattenfall</b>	<ul style="list-style-type: none"> <li>• Managing an increased amount of intermittent energy</li> <li>• More locally produced energy</li> </ul>	<ul style="list-style-type: none"> <li>• Increased amount of electric vehicles</li> <li>• More transparency of electricity consumption for end consumer</li> </ul>	<ul style="list-style-type: none"> <li>• Power-based and time differentiated tariffs</li> <li>• The EU Commission's <i>Energy Efficiency Directive</i></li> </ul>	<ul style="list-style-type: none"> <li>• Low willingness to invest if user volume is low.</li> <li>• Limited room for pilot projects</li> <li>• Risk of moving peaks in demand as opposed to shaving them</li> </ul>
<b>E.ON</b>	<ul style="list-style-type: none"> <li>• Dimensioning the grid according to demand</li> <li>• Managing an increased amount of intermittent energy</li> </ul>	<ul style="list-style-type: none"> <li>• Behavioural based business models</li> <li>• Increased energy consumption</li> </ul>	<ul style="list-style-type: none"> <li>• The EU commission's Clean Energy for Consumers package</li> <li>• Smarter households</li> <li>• intermittent energy</li> <li>• Power-based tariffs</li> </ul>	<ul style="list-style-type: none"> <li>• Low electricity prices entail little economical incentives for end-consumers to install the DCB</li> </ul>
<b>Svenska Kraftnät (SVK)</b>	<ul style="list-style-type: none"> <li>• Managing intermittent energy</li> <li>• Charging of electric vehicles</li> </ul>	<ul style="list-style-type: none"> <li>• Increased investments for the grid and power lines</li> <li>• Energy storage</li> </ul>	<ul style="list-style-type: none"> <li>• Power-based and time-differentiated tariffs</li> </ul>	-

<b>Sala Heby Energi elnät (SHE)</b>	<ul style="list-style-type: none"> <li>Managing an increased amount of intermittent energy</li> <li>Charging of electric vehicles</li> <li>Micro production</li> </ul>	<ul style="list-style-type: none"> <li>Charging of electric vehicles</li> <li>Micro production</li> <li>Lower electricity prices</li> </ul>	<ul style="list-style-type: none"> <li>Power-based and time-differentiated tariffs</li> <li>Evening out power peaks</li> <li>Decrease transmission losses</li> </ul>	<ul style="list-style-type: none"> <li>The interest for demand side flexibility</li> <li>Costs vs savings</li> </ul>
<b>Sollentuna Energi och Miljö (SEOM)</b>	<ul style="list-style-type: none"> <li>Solar panels</li> <li>Electric vehicles</li> <li>Management of intermittent load</li> <li>Supplier Centric business model</li> </ul>	<ul style="list-style-type: none"> <li>Solar panels</li> <li>Electric vehicles</li> <li>Power-based tariffs</li> <li>More value based organizations and consumers</li> </ul>	<ul style="list-style-type: none"> <li>Power-based and time-differentiated tariffs</li> <li>Simplify customers' lives</li> <li>Increased amount of electric vehicles</li> </ul>	<ul style="list-style-type: none"> <li>The DCB has to be simple to install and not require large investments and refurbishing</li> </ul>
<b>Fortum - Charge and Drive</b>	<ul style="list-style-type: none"> <li>Solar economy</li> <li>Managing an increased amount of intermittent load</li> </ul>	<ul style="list-style-type: none"> <li>Demand side flexibility</li> <li>Increased amount of electric vehicles</li> <li>Solar energy</li> <li>Energy storage</li> </ul>	<ul style="list-style-type: none"> <li>Desire to maintain balance</li> <li>Tool for managing new technologies on the grid</li> </ul>	<ul style="list-style-type: none"> <li>How to communicate value to customers, investment vs results</li> </ul>

#### 4.2.2.1 Challenges for the Energy Market

According to the representative from Vattenfall a common challenge for the energy market today is associated with a more volatile energy production and less predictable energy consumption, see *Figure 17*. Energy production is becoming more volatile due to the increased amount of renewable energy sources and locally produced energy that is being integrated into the energy system. At the same time energy consumption is being used within new areas and industries, such as electric vehicles. A possible way to solve this future problem, according to Vattenfall's representative, is through incorporating more demand side flexibility in the energy system.

Fortum Charge and Drive's representative stated that on a general basis achieving 100% solar economy is a challenge for the energy system. With solar economy, he meant that all energy is generated directly or indirectly from the sun, i.e. solar power, wind power and hydro power. The main challenge is that these resources are intermittent and difficult to control, which is why demand side flexibility is presented as a potential solution for the issue, see *Figure 17*.

The representative from E.ON explained how the grid today is dimensioned for stable energy production and volatile energy consumption, with a one way flow of energy from the production plant to the end consumer. However, with more locally produced energy, e.g.

micro production or solar panels, people can sell the energy they produce to the grid which entails a two-way flow of energy. With an increased energy production, many power lines that previously were over-dimensioned now will be under-dimensioned. Related to this is the challenge of deciding whether to build more power lines or to connect new buildings to the already existing power lines. The representative from E.ON believed that building new power lines would be an attractive solution, alternatively harnessing solutions such as dynamic line rating, which can monitor the load if the grid is overloaded.

Aside from energy production becoming more volatile the representative from E.ON also mentioned that when the grid becomes more strained, as when transporting more renewable energy, such as wind power from Öland to mainland, transmission losses increase.

Another challenge, although not as prioritized, is the occurrence of power peaks on the grid during hours with high electricity demand. Power peaks entail transmission losses which are costly and the costs are covered by the fees that end consumers pay to the grid owner. Both Ellevio and Vattenfall, however state that this issue is minor and not in focus compared to building, monitoring and upgrading the existing grid. During interviews with Vattenfall it was discussed how small, local grids are more vulnerable to power peaks compared to bigger grid companies. The interviewee from Vattenfall also mentioned that there are more challenges with energy shortage and capacity failures locally, for example in Uppsala, than nationally.

Sala Heby Energi Elnät (SHE), which is a municipally owned electricity company, agreed that the increased amount of intermittent and renewable energy is a challenge for the energy system, see *Figure 17*. When the amount of base power decreases, it has implications for regional electricity grids. The representative from SHE also pointed out how the increased emergence of charging stations and micro production has implications on the electrical grid. Charging stations often entail that an increased amount of power is extracted from specific areas, at the same time micro production increases the size of voltage that is extracted. These challenges require new ways of planning, for example through building and equipping the grid in a coarser manner. Other solutions to the issues that SHE presented were new tariff structures, new metering systems or in worst case, disconnection of customers. SHE themselves introduced power-based tariffs as a mean to decrease costs to overhead grids.

Sollentuna Energi och Miljö (SEOM), which also is a municipally owned electricity company, agreed with the other utilities regarding how the increase of intermittent energy and electric vehicles creates new demands for the electric grid, see *Figure 17*. Another challenge that they spoke about was the transition towards a supplier centric business model, where the electricity retailer is responsible for all customer contact. The traditional customer contact with the grid owner which exists today, will be removed, and instead the electricity grid fee will be paid via the electricity retailer. Customers who are connected to different grids, geographically widespread, will all receive customer service from the electricity retailer, which entails that the retailer has to have good knowledge of what is happening on multiple grids across the country. Another issue that occurs with a supplier centric model is that the

electricity retailer has to have insight into the different grid owners' business models and tariff structures, which can become a future challenge if standards don't emerge.

A more important challenge to be focused on, according to representatives from Ellevio, is how to motivate high investment costs when renewing aged grids. Although, Ellevio's grids are functioning today, large parts of their grids are old and worn out. The company wants to renew the old grid, but sometimes it can be a challenge to gather money for the investment required, since it is difficult to motivate why perfectly functioning grid lines need to be refurbished. According to both interviewed representatives from Ellevio, a challenge is therefore how to make customers understand what they are paying for. Gathering money for these kind of investments can not only come from increasing prices towards end consumers, since the grid market in Sweden is monopolized per area, the costs therefore must be motivated and approved from authorities. The representative from E.ON mentioned how grid companies all over Sweden, both large and small operators, work hard with updating and monitoring their grids in order to be as stable as possible for the future. These investments are done to modernize the grid in order to integrate more renewable energy production and microproduction.

When asked why Ellevio want to renew the old grid, despite having good functionality, the representative answered that technological advancements in society, such as increased number of electrical vehicles and more energy-efficient machines and appliances, will have a decreasing impact on the total energy consumption in the future. This means that the demand for electricity will decrease, even if gradually, which leads to operating costs for the grid becoming more expensive. Therefore, as demand decreases, grid companies have to renew the old grid network, as well as build more facilities, and everything is to be paid from fewer kWh (less demand). A potential solution for solving the issue is, according to all interviewees, to transition from energy-based tariffs to power-based tariffs.

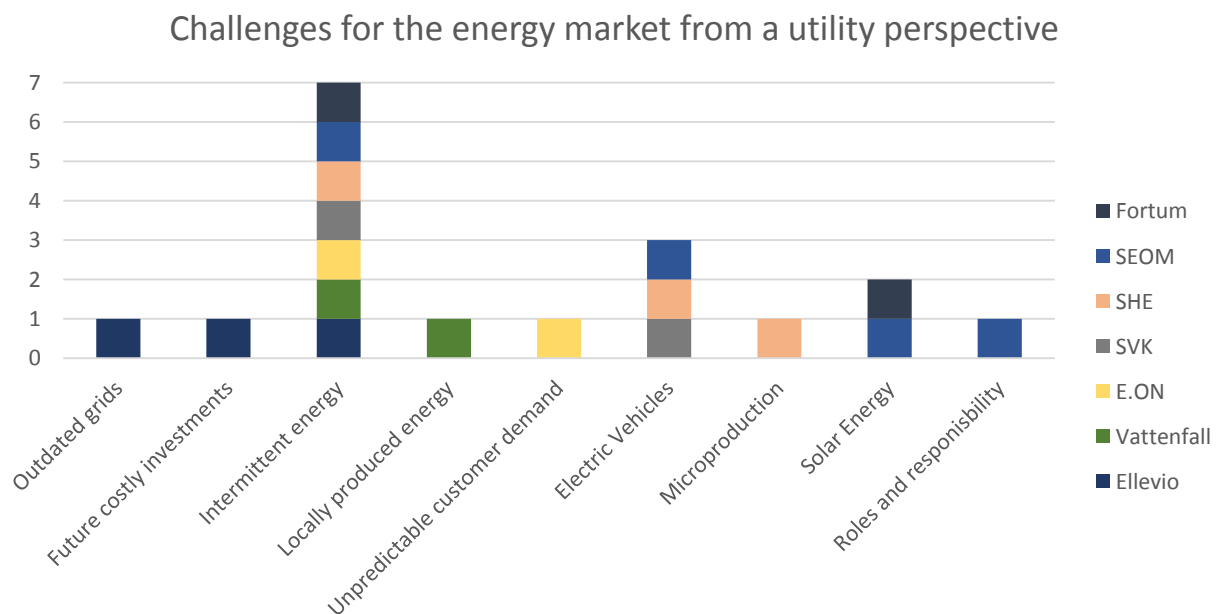


Figure 17. Summary of utilities' perception of challenges for the energy market.

#### 4.2.2.2 Future Trends for the Energy Market

Common future trends that were identified during the interviews were that households are becoming smarter and that more locally produced energy will become common as subventions for solar panels will increase in the future, see *Figure 18*. One of the representatives from Ellevio also mentioned that with locally produced energy the concept of energy storage in batteries will also become more popular. The interviewee from E.ON believed that Internet of Things (IoT) will become a lot more integrated in households, letting them communicate wirelessly and allow for more variable information to be collected. The representative from E.ON also believed that more companies will emerge in the field of smart energy control for households in the future and the more information data these companies can gather from their customers, the smarter systems they can build, resulting in houses having systems that automatically operates their energy usage. These types of systems may utilize energy in a completely new way which can affect how grid companies today operate and monitor their grids in the future.

SHE presented the emergence of more charging stations and micro production as possible future trends. The representative from SHE also pointed out how lower electricity prices may be a possible trend for the future which can affect the energy system. If electricity is not profitable, then many power plants may close down. Today the European energy system is connected, allowing for export when production is larger than demand. In the future energy market storage and utilizing excess energy may become reality, which also can become a potential solution if energy prices are non-profitable.

Another trend mentioned by the representative from E.ON is that business models will become more behavioural based and that the business models will come to change from energy-based tariffs to power-based tariffs. The belief of future power-tariffs was shared by the interviewees from Vattenfall, SEOM and Ellevio. Power-based tariffs are based on the consumers' highest power peaks per month, the number of peaks varying based on company, rather than the mean value of the electricity price on Nord Pool as is the case today. This will give end consumers the opportunity to monitor their energy consumption in a new way.

SEOM's representative mentioned how working more towards values is a future trend, especially as customers become more conscious and active on the energy market. SEOM is owned by the inhabitants of Sollentuna, which vote for the politicians that are part of SEOM's board. SEOM's vision is to simplify everyday life and make Sollentuna more sustainable. The representative emphasized how SEOM in a sustainable way want to provide the service that customers need. Aiming to maximize the revenue cap is not SEOMs goal, as this would impact the customers through higher tariffs. Instead, SEOM focus on fulfilling their vision, simplifying everyday life, helping people live smarter and become more resource efficient.

Fortum Charge and Drive's representative saw electric vehicles as a big trend for the future, which will create new demands for the grid. An electrified fleet of vehicles will increase the amount of energy used, and charging stations will result in more power being extracted at

specific points. Depending on the character of the charging stations, e.g. fast stations, normal speed etc., the extracted power will vary in size. Electric vehicles to grid solutions could also become a possibility in the future, where the car battery can contribute to balancing the frequency on the grid. Another solution could be to integrate demand side flexibility into the system in order to cause as little strain as possible on the grid or avoid power peaks. The representative also saw solar panels and energy storage as future trends for the energy system, both as separate technologies but also in combination with one another.

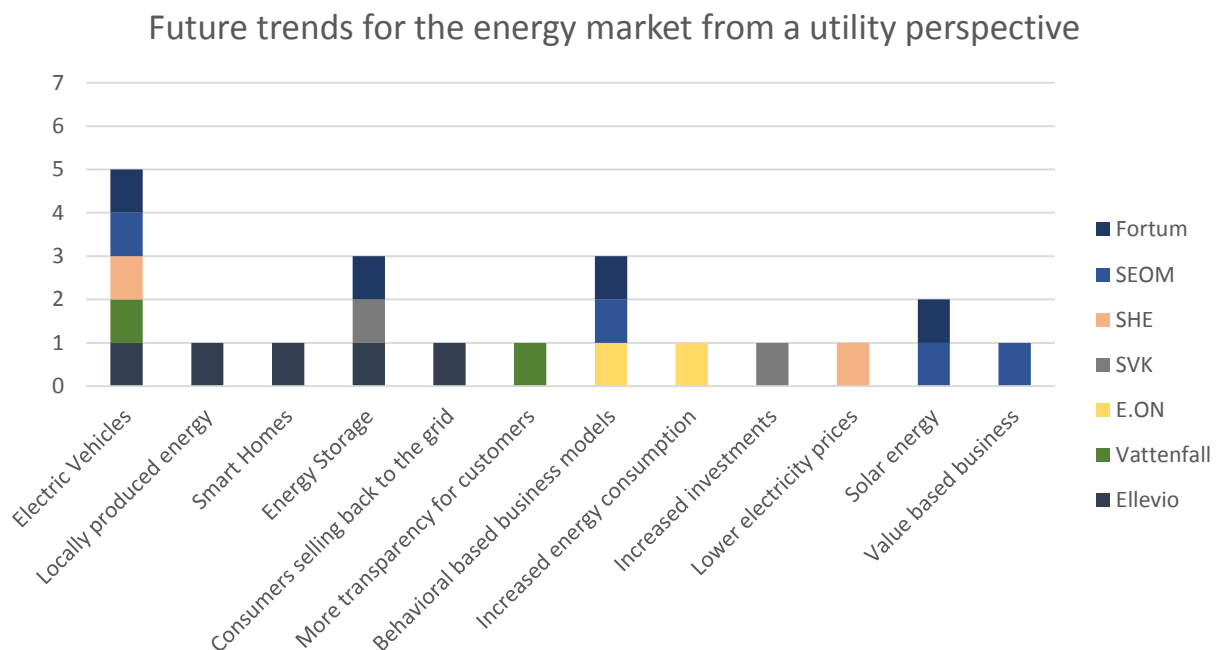


Figure 18. Summary of utilities' perception of future trends for the energy market.

#### 4.2.2.3 Supporting factors for the DCB

When the DCB was presented during the interviews discussions about how future trends will work as supportive factors, favouring the need for DCBs emerged, see *Figure 19*. For example, the interview at Vattenfall opened up discussions about future tariff models and the interviewee claimed that the fixed month tariffs that are common today will transition towards time-differentiated tariffs. This was also mentioned by the representative from E.ON. Time-differentiated power-based tariffs will be introduced more widely in the future in the hopes of having better energy balance on the grid. Better balance on the grid will be achieved by end consumers' awareness of electricity price per hour and this might result in them shifting their energy usage during peak hours to off-peak hours. This is what the interviewees referred to as demand side flexibility and all representatives from E.ON, Vattenfall and SVK mentioned how demand flexibility will have a bigger part in the future energy market due to the increased amount of renewable energy sources and micro production.

One of the underlying causes for time-differentiated power-based tariffs, according to the representative from Vattenfall, is the need of a more accurate amp size for households. End

consumers will gain from power-based tariffs by paying for their actual power usage only and not more. Today the amp sizes are fixed to specific numbers and it is not dynamic, but with power-based tariffs and potential demand flexibility solutions the customer will have a more flexible amp size for its household, and this will, according to representatives from E.ON, Vattenfall and SVK, bring value to the customer.

SHE already today have a power-based tariff in place, which they believe speak in favour for the DCB. The power-based tariff is made up of the mean of the five highest levels of power that were extracted during a month between the 7 AM to 7 PM. SHE have been using the power-based tariff since 2000 and have through this also tried to educate their customers to become more aware of how they consume energy. The power-based tariff is also an effort in decreasing peaks in demand on the electrical grid. When peaks in demand occur it often entail that larger payments to the overhead electrical grid have to be paid, resulting in an expensive cost for a small issue. When peaks in demand are diminished, and a more even load can occur, smaller wires or other materials could be used. SHE's representative also pointed out how a more even load could also decrease transmission losses, which are seen as a non-effectible cost. There exists a limit as for how big losses the companies can have, if these limits are exceeded the revenue frame is reduced. And if the losses are small in relation to the set goal than the revenue frame is increased. If the DCB can help manage transmission losses it may work as an encouraging factor to even out loads.

SEOM's business model also includes power-based tariffs which is something that their representative believed could work in favour for the DCB. SEOM was the first utility in Sweden to incorporate a power-based tariff, however, the transition to a power-based tariff required that the electrical meters were replaced with hourly measuring meters. As opposed from SHE, SEOM's tariff is based on the mean of the three highest levels of power that are extracted between the hours of 7 AM to 7 PM. SEOM's transition to a power-based tariff was based on the belief that it better reflects true costs. The representative presented the example of a customer which has a large electricity need and extracts high levels of power at certain hours. In order for these amounts of power to be extracted the right capacity and infrastructure must exist. Therefore, the customers contribute to financing this through the power-based tariff. SEOM see the business model as an initiative to reduce power peaks. SEOM's representative also pointed out how power-based tariffs can help facilitate demand side flexibility.

One of the representative from Ellevio gave an example of a case situation where the DCB could be introduced easily and gain volume in number of customers. According to the representative many old buildings in Stockholm have distribution boards that have not been updated since the beginning of the 20th century. Nowadays, real estate owners and apartment owners update these old distribution boards, which presents opportunities for the DCB to be installed. The other representative from Ellevio saw peak load as a supportive factor for grid companies to be interested in the DCB. Even though peaks on the grid are not a prioritized challenge today, the interviewee from Ellevio explained that there might be a scenario in the future where load peaks on the grid will be significant and in that case the grid company



needs to strengthen its grid, for example by building new grid lines. As building new grid lines requires time and money it could potentially be beneficial to harness new solutions, and this is where the DCB could help. The representative meant that the DCB could deliver value to grid companies if it would be the alternative to building new grid lines.

Fortum Charge and Drive’s representative spoke about how the integration of technology such as energy storage, solar panels and electric vehicles creates new demands for the grid. The DCB could perhaps become a tool which facilitates this integration through for example demand side flexibility.

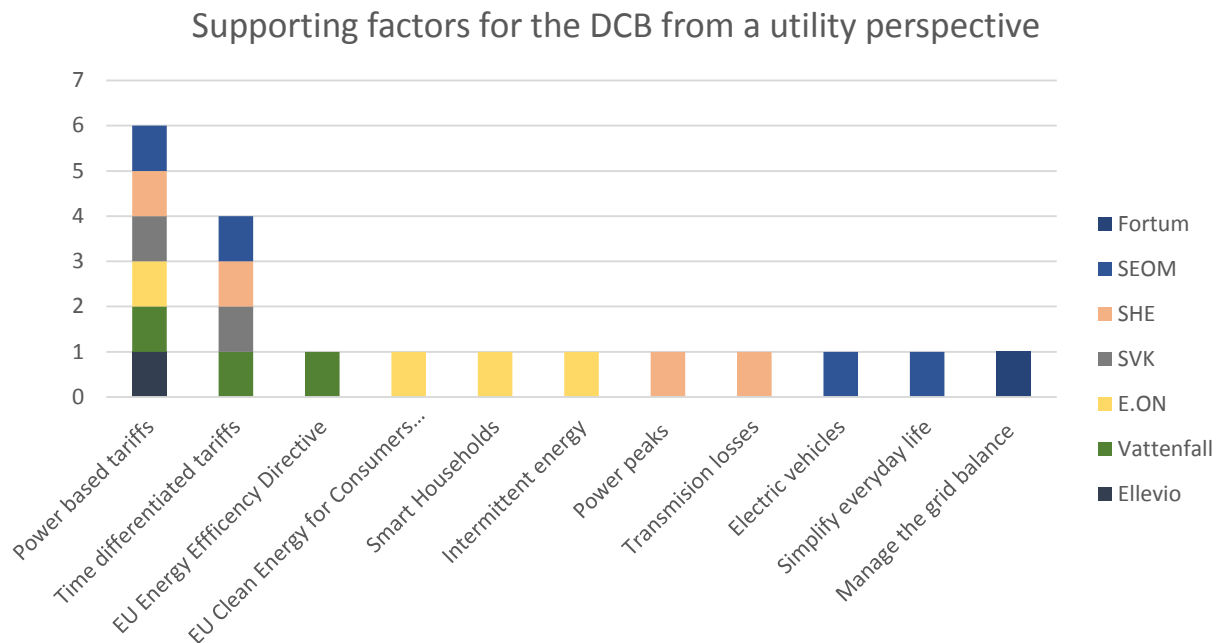


Figure 19. Summary of utilities’ perception of supporting factors for the DCB.

#### 4.2.2.4 Perceived Risks and Barriers

The majority of the interviewees touched upon the subject of low electricity prices today, however, E.ON and Fortum mentioned how electricity prices may be too low for the DCB to be economically justified to install in customers’ homes, see *Figure 20*. The customer has to make relevant cost savings for them to consider a demand flexibility tool in their house, and with low electricity prices there are no direct incentives for customers to install the DCB themselves. Furthermore, representatives from Ellevio and Vattenfall believed that grid companies would not be interested in the DCBs if there was no customer volume to show for first. If customers showed interest in DCBs it could work as a driver for grid companies to join partnership with Manetos, but for now, grid companies want to focus on their core business as grid owners, meaning safe and secure delivery of electricity. This opinion was shared by the majority of interviewees.

SEOM’s representative pointed out how a barrier for the DCB could be that customers may be hesitant to install it if large investments and refurbishments for the buildings are required. Simplicity and home automation were values which were perceived to be important for

customers. If the installation of DCBs would require large reconstruction, a potential solution could be to focus only on connecting the DCBs the buildings heat pumps and charging station for electric vehicles, as these appliances were deemed to be very interesting for power control. Fortum Charge and Drive’s representative also emphasized how it can be difficult to communicate values to the customers, i.e. what they get, what they pay for and their results. Therefore, packaging and creating a simple and attractive customer interface is of importance.

### Percieved risks and barriers for the DCB from a utility perspective

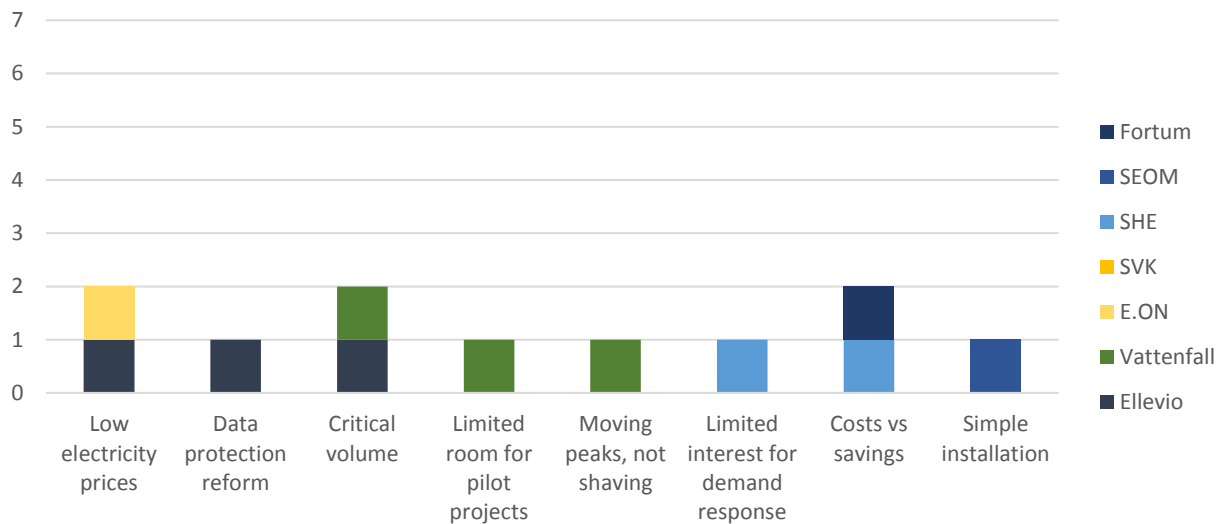


Figure 20. Summary of utilities’ perception of barriers and hinders for the DCB.

### 4.2.3 Electricity Retailers

The following chapter presents the electricity retailers' view on the challenges and trends for the energy market from a retailer perspective. Incentives and challenges for the DCB are also discussed from an electricity retailer perspective. *Table 5* presents an overview of the retailers' opinions and the given answers are presented more in detail in the following subchapters.

Table 5. Overview of electricity retailers' opinions towards the DCB.

	<b>Challenges for the Energy Market</b>	<b>Future Trends for the Energy Market</b>	<b>Supporting factors for the DCB</b>	<b>Perceived Risks and Barriers for the DCB</b>
<b>God El</b>	<ul style="list-style-type: none"> <li>• Great competition on the market, 130 electricity suppliers in Sweden</li> <li>• Low margins</li> <li>• Organic growth</li> <li>• Increased responsibility for suppliers</li> </ul>	<ul style="list-style-type: none"> <li>• New contracts</li> <li>• Power-based tariffs</li> <li>• Supplier centric model</li> <li>• Less materialism and more consumption according to values</li> </ul>	<ul style="list-style-type: none"> <li>• Power-based and time-differentiated tariffs</li> <li>• Home automation</li> <li>• Dynamic taxes</li> <li>• Contributing to the bigger picture</li> </ul>	<ul style="list-style-type: none"> <li>• Consumers may resist altering their lifestyle for demand side flexibility</li> <li>• Low electricity prices entail little economical incentives for end-consumers to install DCB</li> </ul>
<b>Bixia</b>	<ul style="list-style-type: none"> <li>• How value is packaged towards customers</li> <li>• Increased amount of intermittent energy</li> <li>• Future payment model for grid owners</li> </ul>	<ul style="list-style-type: none"> <li>• Solar energy</li> <li>• Energy storage</li> <li>• More energy conscious customers</li> <li>• Increased amount of electric vehicles</li> </ul>	<ul style="list-style-type: none"> <li>• Energy conscious customers</li> </ul>	<ul style="list-style-type: none"> <li>• Contracts and agreements with customers</li> </ul>

#### 4.2.3.1 Challenges for the Energy Market

According to the representative from GodEl one of the main challenges for electricity retailers is the great competition on the market, see *Figure 21*. He described how there in Sweden exist 130 electricity retailer companies, whereas 20-30 of the companies are competing for all of the customers in Sweden. Furthermore, the margin on the electricity production is low, resulting in many electricity retailers having difficulties in making ends meet. The representative described this as being a result of the competitive market. GodEl have not engaged in this activity, pricing is not an issue for GodEl, however for many of their competitors are facing challenges regarding pricing.

According to the GodEl’s representative another challenge that is experienced, is the difficulty in growing organically, which also is an effect of the competitive market. GodEl’s representative described how many companies grow quickly through mergers, as opposed to growing organically. A challenge for many electricity retailers has been marketing, which often does not have an impact that matches the expected results. Furthermore, the transition towards a supplier centric market model is also a challenge which sets new demands on the role and responsibility of the electricity suppliers.

The representative from Bixia emphasized how one of the biggest challenges for electricity retailers is how to deliver and package relevant offers for customers, see *Figure 21*. Electricity is perceived by the majority as a low interest product, which makes it important for suppliers to create relevant offerings. In the future energy system an increased amount of clean energy is to be integrated, and Bixia today are already taking active steps towards this by for example taking part in solar energy projects. However, if consumers produce more energy themselves it decreases the demand from both energy retailers and electrical grid companies. Bixia’s representative pointed out how it is better for Bixia to take part in this type of market and see how it can be utilized in order to create good alternatives and options for customers. An idea could be that Bixia could help customers sell their produced energy to the grid. The issue of decreased demand however could significantly impact the grid companies as they are the ones who pay for infrastructure. The grid owners’ base for payments decreases when energy is produced inside the electricity meter. Therefore, the future payment model for electric grid companies is believed to be a challenge.

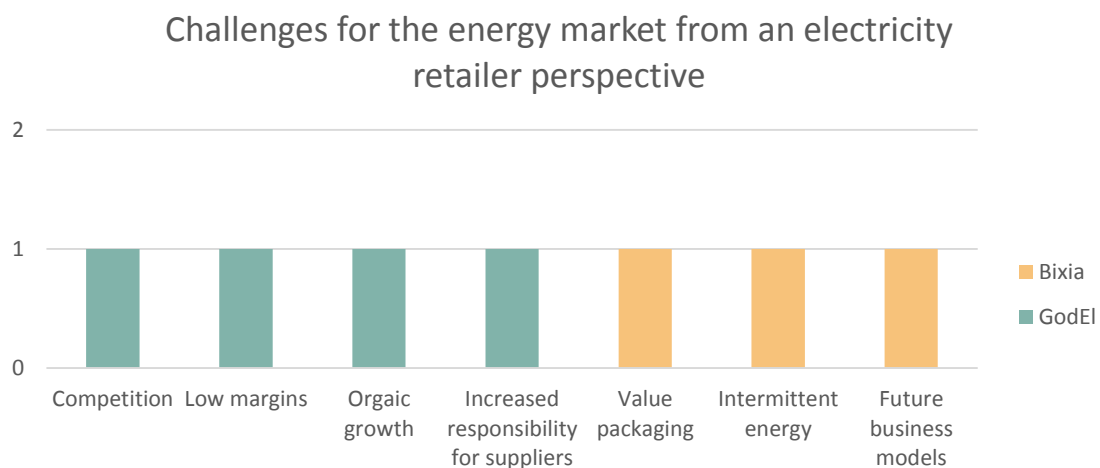


Figure 21. Summary of electricity retailers’ perception of challenges for the energy market.

#### 4.2.3.2 Future Trends for the Energy Market

The GodEl representative saw power-based tariffs as a future possibility which could work in favour for the DCB, see *Figure 22*. Politicians today see demand flexibility as an increasingly important aspect for the future energy system, especially in order to utilize more intermittent energy. In order to achieve this the representative pointed out how new contracts and tariffs may be developed and introduced.

According to GodEl’s representative the transition to a supplier centric market model is an action which will have an impact on the energy market in the future. Today, the customer is in contact with both the grid owner as well as the electricity supplier, in the future however customers will only have contact with the electricity supplier. This entails that the supplier’s role and responsibility will change, as they are now responsible for both network charges and consumption costs. The representative emphasized how for the customer the change won’t be significant. Behind the scenes however there will be large changes, as all communication will pass through a hub where all information of the system is to be available.

Furthermore, the representative from GodEl believed that profiling and positioning of energy companies is a future trend. He means that consumers are becoming less materialistic and instead consuming according to their values. Identifying oneself a the product, as opposed to identifying with a product’s status, is a trend that will affect how companies brand themselves, see *Figure 22*.

Bixia’s representative believed that in the future, especially in new construction projects, solar panels and energy storage will come to play an important role, see *Figure 22*. These technologies could also be combined with one another, for example by having solar panels charge a battery which can then be used when energy prices are high or for charging an electric vehicle. The representative emphasized how the timing for when solar panels, energy storage and electric vehicles will have a significant breakthrough is difficult to predict. He believes that it will be heavily dependent on how regulations and subsidies drive customers’ actions. Bixia’s representative also saw how customers are becoming more energy conscious, see *Figure 22*.

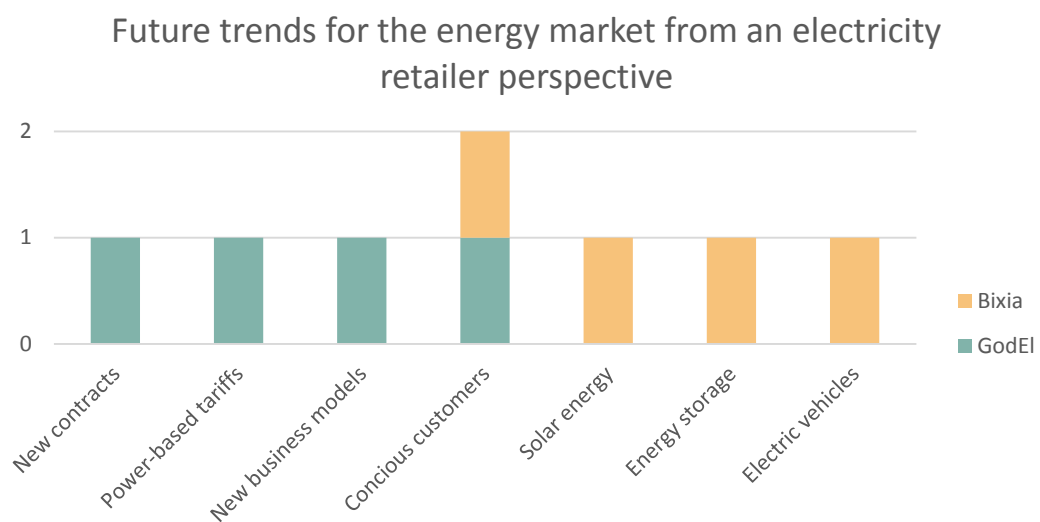


Figure 22. Summary of electricity retailers’ perception of future trends for the energy market.

#### 4.2.3.3 Supporting factors for the DCB

GodEl's representative presented how a future transition to power-based tariffs and new ways of contracting can act as an incentive for customers seeking ways to reduce their electricity consumption. Power-based tariffs, based on when electricity is consumed, can lead to higher electricity costs. Therefore, the DCB may be able to benefit from a power-based tariff as it allows for control of load and consumption.

According to God El's representative more dynamic taxes could impact the fluctuations in consumption and thereby create incentives for the DCB. The representative also pointed out how solutions that don't require customers to change their lifestyle or which reduce the customers' activities is something that creates value. The feeling of contributing to the big picture, for example by purchasing renewable energy such as GodEl's customers, can also contribute with value. Bixia also shared the opinion of energy consumers becoming more energy conscious, and that it could act in favour of the DCB. *Figure 23* presents an overview of supporting factors for the DCB from an electricity retailer perspective based on the answers given in the interviews.

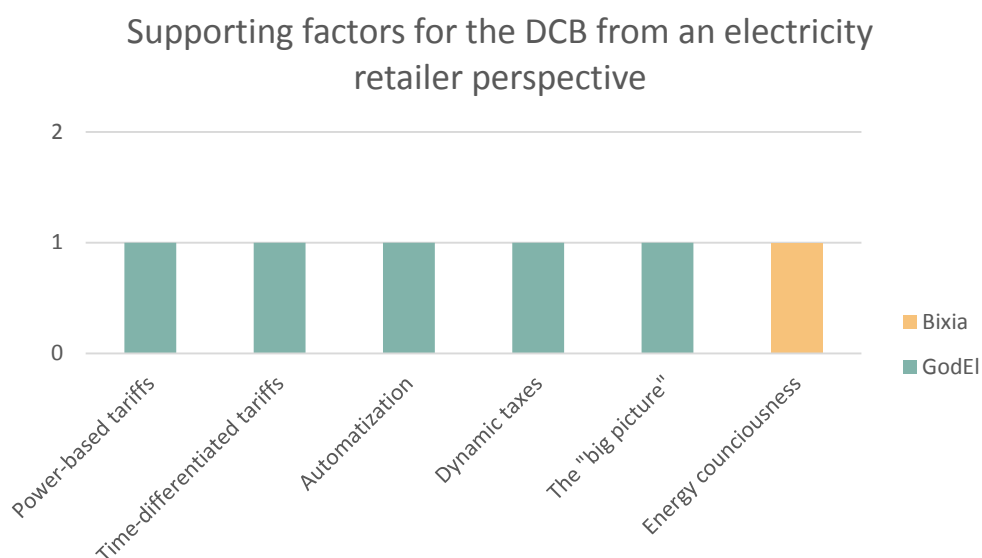


Figure 23. Summary of electricity retailers' perception of supporting factors for the DCB.

#### 4.2.3.4. Perceived Risks and Barriers

GodEl's representative presented a main challenge for the DCB, and control instruments in general, namely how consumers are not ready nor willing to change their lifestyle. Currently the difference between the cheapest and most expensive electricity price on the markets is insignificant. He believes that in order to achieve demand side flexibility and peak shaving, the large mass has to be included. The large mass however won't join in until their situation becomes more critical, such as if electricity prices were to become more volatile. Customer maturity is therefore seen as a significant risk for the DCB. Another important aspect that could become a barrier for the DCB, according to the representative from Bixia, is how contracts with customers are designed, they need to deliver value to customer through relevant and reasonable offerings. The above presented challenges for the DCB are illustrated in *Figure 24*.

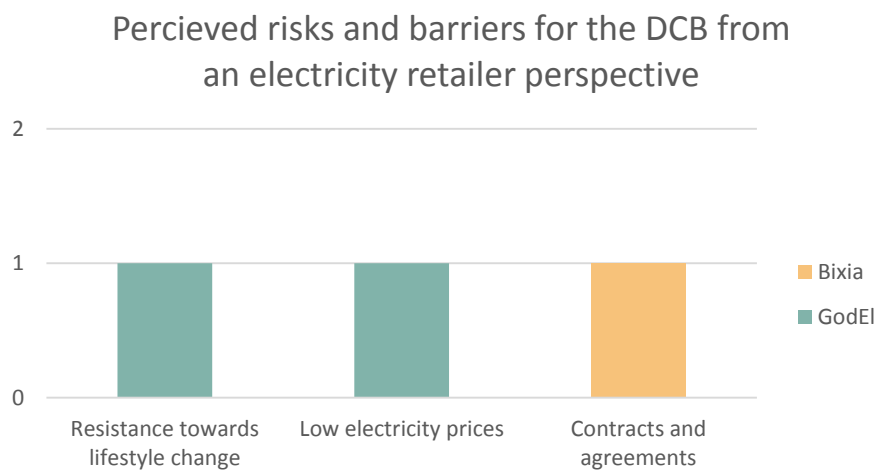


Figure 24. *Summary of electricity retailers' perception of risks and barriers for the DCB.*

#### 4.2.4 Real Estate Companies

The following chapter presents a table with an overview of the interviewed real estate companies' opinions, see *Table 6*, as well as subchapters going more into detail of the answers. The studied factors are real estate companies' challenges for energy in buildings, trends associated with energy in buildings as well as incentives and perceived risks for the DCB.

Table 6. *Overview of real estate companies' opinions towards the DCB.*

	<b>Challenges for Energy in Buildings</b>	<b>Future Trends for Energy in Buildings</b>	<b>Supportive factors for the DCB</b>	<b>Perceived Risks and Barriers for the DCB</b>
<b>Akademiska Hus</b>	<ul style="list-style-type: none"> <li>• Difficult to motivate investments, costs vs savings</li> <li>• Difficult to determine lifetime of traditional MCBs due to wear and tear.</li> </ul>	<ul style="list-style-type: none"> <li>• Energy savings, purchasing less and generating more</li> <li>• New and efficient technologies</li> <li>• Collaboration with tenants</li> <li>• More energy conscious tenants</li> </ul>	<ul style="list-style-type: none"> <li>• Akademiska Hus are currently conducting a similar project with smart MCBs</li> <li>• Efforts in making tenants more energy conscious</li> <li>• Wish to decrease amount of purchased energy</li> </ul>	<ul style="list-style-type: none"> <li>• Shared responsibility for electricity between real - estate company and tenants</li> <li>• MCBs are not used in their buildings</li> <li>• Potential for demand side flexibility</li> <li>• Manual control of power failure</li> </ul>
<b>Vectura</b>	<ul style="list-style-type: none"> <li>• Little transparency</li> <li>• Inefficient dimensioning</li> <li>• Tenants are responsible for all subscriptions</li> </ul>	<ul style="list-style-type: none"> <li>• Lower costs for technology</li> <li>• Weather based prognosis</li> <li>• Smarter homes</li> <li>• Increased transparency and awareness</li> </ul>	<ul style="list-style-type: none"> <li>• Desire to control and monitor buildings</li> <li>• Interest from tenants</li> <li>• Simplicity, fewer site visits</li> <li>• Proactive data collection</li> <li>• Long term ownership</li> </ul>	<ul style="list-style-type: none"> <li>• Relationship between tenants and owner, who leads development</li> <li>• Who has access to information and data? No monitoring from external actors</li> </ul>



#### *4.2.4.1 Challenges for Energy in Buildings*

The representative from Akademiska Hus stated that they have no issues or challenges with power supply. At the Royal Institute of Technology (KTH), where Akademiska Hus owns the buildings, they have their own system which they are responsible for and where power is supplied from Ellevio. Akademiska Hus have themselves studied the losses in their system which were concluded to be minimal and not a perceived issue. Furthermore, the buildings at KTH are equipped with district heating and remote cooling. The electricity usage is low, Akademiska Hus are mainly responsible for the operation room, elevators, fans etc. The remaining electricity usage belongs to the buildings' tenants.

According to Vectura's representative it is the tenants who are responsible for the buildings' energy subscriptions. However, it often occurs that tenants do not think about turning off lights when they leave a building or turning off fans etc. Being able to control activities like these is a challenge today, but a goal for the future according to Vectura. Furthermore, as the tenants own the buildings' energy subscriptions it is also they who have to take an active role in order for development and improvements to take place, which can be a challenge if they have little interest within the energy area.

The representative from Vectura also emphasized that a challenge for them is how they have little transparency regarding their buildings' energy consumption. As Vectura is a young company which have not previously focused much on energy, there is great potential for learning more about their buildings and their energy consumption. Many of Vectura's buildings are buildings which have been rebuilt, for example office buildings have been rebuilt into elderly homes. An issue with the rebuilding is if the building's tariff has been adjusted accordingly. Today Vectura only see the electricity bill and not if the amp size is correctly or wrongfully dimensioned, which is perceived as a challenge.

A challenge that the representative from Akademiska Hus presented was how it is difficult to motivate investments, as costs often exceed savings. Akademiska Hus themselves have a goal of decreasing the amount of purchased energy by 50% by 2025. In order to do so they plan to use solar panels or heat pumps, with the aim of increasing the amount of clean energy. A challenge is to involve the tenants in order to achieve savings. Seen to electricity in the buildings, lighting is a potential area in which savings could be achieved. One fluorescent light counts for 36 Watts, which if it were exchanged for a more efficient light could decrease the power by 30-35%. However, the savings do not amount to a sum which is equivalent to the investment, creating a long payback time. There is even a risk that the lights break, and new ones have to be installed before the first light is paid back.

Akademiska Hus representative also pointed out how they do not use MCBs in their buildings, instead they use fuses, which is not as common nowadays. The reason as for why MCBs are not used is because there is an old rule which states that MCBs are not viable as it is impossible to determine how many times the breaker has been triggered and what the current at that point was. As there are many tenants in the buildings, it is nearly impossible to determine these factors. Vectura however mainly have MCBs in their buildings. An overview

of the above presented challenges for energy in buildings are presented in *Figure 25* based on the conducted interviews with real estate companies.

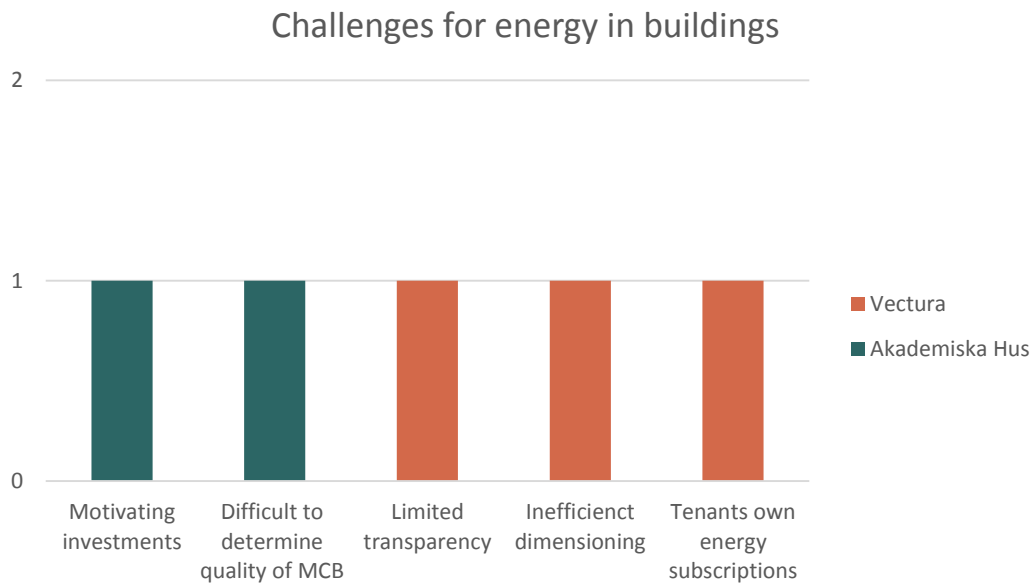


Figure 25. Summary of real estate companies' perception of challenges for energy in buildings.

#### 4.2.4.2 Future Trends for Energy in Buildings

According to the representative from Akademiska Hus the emergence of new and more efficient technologies will increase in the future, see *Figure 26*. As Akademiska Hus have the goal of reducing the amount of purchased energy, and instead generate more themselves the topic of more clean technologies such as solar panels were discussed. Other examples of efficient appliances that were discussed were ventilation and heat control systems. The integration of prognosis control, i.e. climate controlled systems, could help optimize both ventilation and heat control. Furthermore, in order to achieve savings, collaborations with tenants may increase and Akademiska Hus is working towards making their tenants more energy efficient in their electricity usage.

Vectura's representative also emphasized how technology will become more efficient and less costly in the future, see *Figure 26*. A technology that he believed would become more common in the future is weather-based prognosis technologies, where homes themselves can adjust better according to the prevailing climate. He also believed that homes in general will become smarter and have the potential to learn from previous situations and conditions. For example, if many of a household's inhabitants are at home the heating can be turned down as the people themselves generate heat which contributes to maintaining a comfortable temperature. More intelligent solutions were believed to be a trend as well as an increased transparency and awareness from people. According to Vectura's representative people are becoming more aware of energy and interested in what they actually are consuming and paying for.

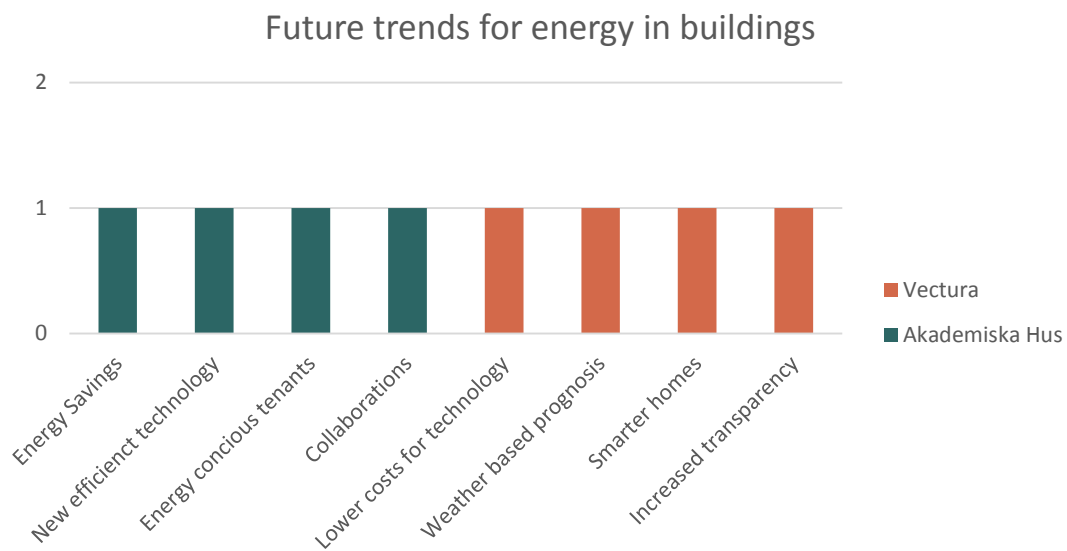


Figure 26. Summary of real estate companies' perception of future trends for energy in buildings.

#### 4.2.4.3 Supporting factors for the DCB

Akademiska Hus representative briefly presented a pilot project which Akademiska Hus themselves are conducting where they are installing smart MCBs in a building. This project entails installing MCBs which are online and through them registering the number of times a breaker is triggered, as well as the size of the current. The project is a way to track the performance of MCBs and the quality of them. Other supporting factors can be Akademiska Hus wish to purchase less energy as well as make their tenants more energy conscious, see *Figure 27*.

As Vectura previously have not focused significantly on the energy area in their business, there were many supporting factors for the DCB which were presented during the interview. The representative emphasized the interest of being able to monitor and control their buildings remotely. Not only is control desired but also more transparency into their energy consumption. A few examples of interesting activities that were presented were remotely controlling of lighting and ventilation, managing power peaks, determining the accurate amp size and identifying electrical malfunctions or abnormalities in the building. Being able to know how the house is “feeling” could also work proactively and decrease the amount of site visits that have to be made for reparations or control.

Vectura's representative also pointed out how they work with long term ownership of buildings which makes it important for them to engage the tenants, see *Figure 27*. Therefore, Vectura take an active role in development of different projects and ideas together with the tenants, such as integrating solar panels.

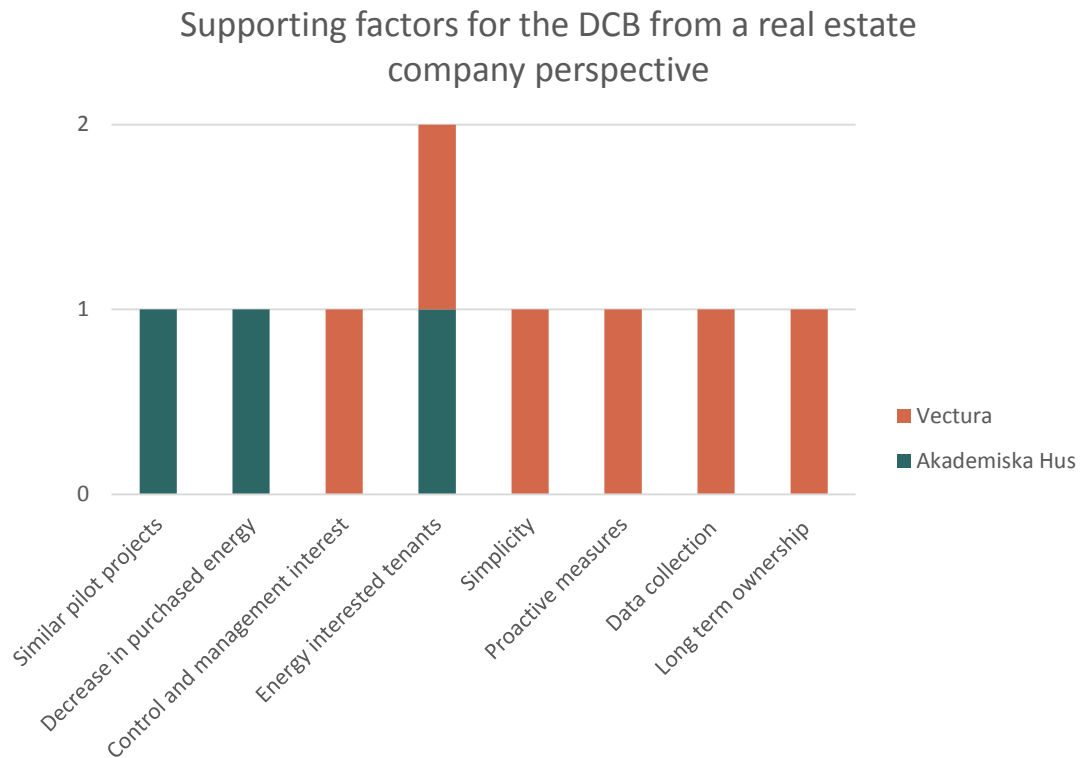


Figure 27. Summary of real estate companies' perception of supporting factors the DCB.

#### 4.2.4.4 Perceived Risks and Barriers

A barrier for the DCB is the fact that Akademiska Hus do not use MCBs in their buildings as they are not deemed to be as reliable and predictable as melting fuses. The Akademiska Hus representative also pointed out how there exists a regulation which states that if a power failure were to occur, the reason for the failure must be overseen manually. A risk with being able to remotely control the DCB, according to the interviewee, is that the reason for the trigger isn't determined. Furthermore, the risk of activating the current when somebody is working with the sockets or appliances in question exists, which could have severe outcomes.

A challenge which exists today, and which could potentially entail a barrier for the DCB according to Akademiska Hus representative, is the fact that real-estate companies and tenants share responsibility regarding the electricity in the building, see *Figure 28*. It is for example not necessarily the real-estate owner who has to replace fuses, the tenants are qualified to do it. However, it is necessary that a replacement is reported to the owner. There is however a misconception between the real-estate owners and tenants regarding this issue.

Vectura on the other hand see a potential issue regarding the relationship between the owner and tenant in form of how much each actor should drive development. As the tenant owns all of the energy subscriptions it is often they who have a lot of power regarding energy. Vectura however also have a lot of ideas and want to take an active role in the development, therefore

cooperation between Vectura and the tenants is possible. The balance between the actors in the development is therefore of importance, see *Figure 28*.

Vectura’s representative also pointed out how monitoring services allow for more control, however, who has access to the data and how long it is stored presents a challenge. Safety and integrity are important aspects, the representative described how they themselves want to be able to have control and monitor their buildings. Allowing an external party to take part of their data or have remote control over certain functions in their buildings was seen as a risk.

A final challenge which the Akademiska Hus representative brought up was that the issue of peak demand may not be critical enough. According to the representative the greatest potential for savings regarding electricity would be though lighting, however these savings would most likely not exceed the investment costs.

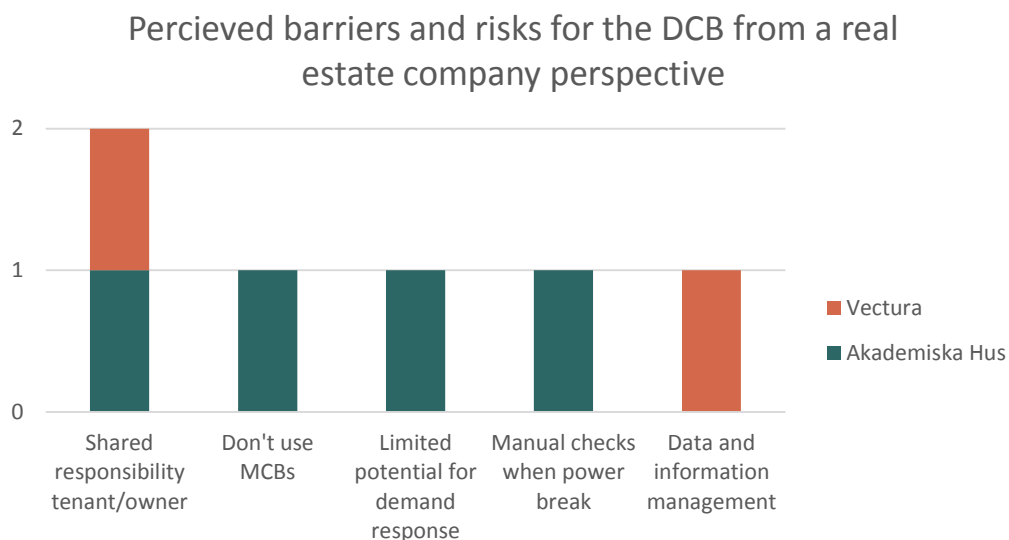


Figure 28. Summary of real estate companies’ perception of barriers and risks for the DCB.

#### 4.2.5 Experts and Researchers

The following chapter contains the view on DCBs, both incentives and risks, as well as challenges for the energy system and future trends from an expert and researcher point of view. *Table 7* presents an overview of the discussed topics from the interviews, and the following subchapters present the answers in more detail.

Table 7. Overview of experts and researchers' opinions towards the DCB.

	<b>Challenges for the Energy Market</b>	<b>Future Trends for the Energy Market</b>	<b>Supporting factors for the DCB</b>	<b>Perceived Risk and Barriers for the DCB</b>
<b>Lennart Söder</b> <i>Professor in Electric Power and Energy Systems at KTH</i>	<ul style="list-style-type: none"> <li>• Regulations towards grid companies</li> <li>• Lack of incentives for energy players</li> </ul>	<ul style="list-style-type: none"> <li>• Increase of electricity demand</li> <li>• More buildings and data centres</li> </ul>	<ul style="list-style-type: none"> <li>• Municipal-owned grid companies</li> <li>• Power reserve</li> </ul>	<ul style="list-style-type: none"> <li>• Expensive to develop = expensive for customer</li> </ul>
<b>Cajsa Bartusch</b> <i>Researcher in market based policy instruments in the electricity market</i>	<ul style="list-style-type: none"> <li>• Information and knowledge sharing with customers</li> <li>• Transparency and design towards customer</li> </ul>	-	<ul style="list-style-type: none"> <li>• Power-based and time differentiated tariffs</li> <li>• Incentives for demand flexibility are not necessary as long as customers' attitudes can be changed</li> </ul>	<ul style="list-style-type: none"> <li>• Difficult to change customers' attitudes in general</li> <li>• Customers do not know enough about demand side flexibility to engage in it</li> </ul>
<b>Anonymous (referred to as Person X)</b> <i>Expert analyst – energy markets and management</i>	<ul style="list-style-type: none"> <li>• An increased amount of intermittent energy</li> <li>• Mobile energy consumption</li> </ul>	<ul style="list-style-type: none"> <li>• Smart metering, data power, smart sensors</li> <li>• Demand side flexibility</li> </ul>	<ul style="list-style-type: none"> <li>• Need for demand side flexibility</li> <li>• Companies within the field are also developing similar technologies</li> </ul>	<ul style="list-style-type: none"> <li>• Risk of hackers and IT-security</li> <li>• Low electricity prices entail little economical incentives for people to install DCB</li> </ul>

##### 4.2.5.1 Challenges for the Energy Market

According to Lennart Söder many of the challenges on the energy market today are rooted in the construction of regulations. He spoke about an issue being that energy distributors today have a revenue cap which is based on the cost of the grid network that the company uses and not on the volume of electricity transferred. The issue with a revenue cap for energy distributors (grid owners), according to Söder, is that grid owners will try to increase their profits by building more and new grid lines instead of investing in smart tools that can allow

them to control loads and achieve peak shaving. Söder argues that private owned grid companies seek to maximize their profits, and one way to do so, without overstepping any regulations, is to expand the grid allowing for more customers to connect to it. If grid companies were to use a technology that could enable them to distribute the same amount of energy that a new grid line could deliver, for example a technology that would enable peak shaving, then the company would rather build a new grid line since that would increase their profit limit (more connected customers entails higher revenues). Söder does however believe that there are grid companies that do not focus primarily on profit, but rather prioritize smart and efficient operation of the grid and he believes that these grid companies most likely are municipal-owned, as Swedish municipal-owned companies usually focus on the welfare of society and not primarily on profit.

Person X emphasized that a big challenge that the energy sector faces is the volatility that renewable energy sources bring to the grid. Person X motivates this by explaining that wind and solar power are not controllable like hydro power, which means that the energy production becomes more unpredictable with an increase of solar- and wind power. He further argues that there are real life examples of where the challenge of integrating renewable energy sources to the energy system has been seen. One example is shown by the problems that Australia experienced when integrating more renewable energy. When Australia started using more renewable energy they also shut down many coal power plants without having extra backup power generation, therefore whenever a power outage occurred due to lack of energy from intermittent energy, they had to start gas turbines which are even more expensive than coal.

The integration of renewable energy sources to the grid was also a challenge that Bartusch spoke about. During the interview, she argued how demand flexibility is more necessary today and in order for demand flexibility to be implemented successfully the need for customer engagement and customers' understanding for demand flexibility is important. However, there exists a challenge for engaging customers as today's communication towards customers is non-existent according to Bartusch. Transparency of energy consumption for each home appliance is what customers demand and that can be used for demand flexibility activities.

Bartusch presented an example of a study she had conducted (*Visualisering av elanvändning i flerbostadshus, 2011*) where tenants in apartment buildings were given a display that presented the amount of power their home was using, without any instruction of how to use the display and what to do with it. After the study, which was conducted over several weeks, Bartusch interviewed the participants about their experience and how they had used the display. The study showed that all participants used the display to calculate how much power different appliances used when they were on. This indicates, according to Bartusch, that people in general are interested in learning how to reduce their energy consumption. This type of feedback is called breakdown feedback of energy consumption.

Another challenge that Person X believes will affect the energy system is that electricity consumption is becoming more mobile. With mobile consumption, he refers to electric vehicles and electric devices that people bring with them, for example wearable technology. Person X gave an example of what an increase in mobile energy consumption can lead to by explaining a case in California where many people own electric vehicles. What happened was that everyone charged their electric vehicle in the evening, when they came home from work. With everyone charging their vehicles at the same time the local grids became overloaded, leading to short circuits and power outages.

During the interview with Söder challenges for energy producers were also discussed. Söder believed that peaks in demand were not a direct issue for energy producers, even though producers sometimes have to start gas turbines in order to manage power peaks, which can be expensive. When a gas turbine has to be started to meet demand, the electricity price will increase and no energy producer, according to Söder, will complain about increased energy prices. Therefore, peaks in demand are not as expensive for energy producers as it may be perceived.

#### *4.2.5.2 Future Trends for the Energy Market*

Söder believes that the electricity demand in Stockholm will increase in the coming years due to the emergence of an increased amount of buildings and data centers which require a lot of energy. Person X believes that future trends include more demand flexibility solutions and more virtual energy suppliers. He believes that sensors, measuring techniques and data power will increasingly be integrated directly into products and make them smart, since such technology is quite cheap already.

Person X also believes that the future will bring more incentives for private households to be more prone to demand side flexibility than what they are today. This is also necessary since, the industry sector is slowly becoming more energy efficient and in the future, it will no longer be the number one sector of energy consumption, but instead residential and commercial buildings will be the number one energy consumers. He means that demand flexibility will have a bigger part to play in the future, especially with all the new smart metering technologies that are being introduced.

Person X also sees a trend of more interconnectivity between countries, especially in Europe. Europe is investing in building large power highways between countries to balance markets in terms of big volumes of energy but also to press down prices since overproduced energy could potentially be sold to neighbouring countries instead of going to waste.

#### *4.2.5.3 Supporting factors for the DCB*

During the interview with Söder it was discussed how big of an issue peaks in demand are, Söder described that the highest demand peaks that he had observed amounted to around 500MW extra from one hour to another. He believed that the DCB could potentially be a



good invention from an energy-system perspective but that it is important to examine the issue on a national and local level as well.

Söder believed that municipal-owned energy companies would be more prone to installing DCBs for their customers as they are not profit oriented in the same way as private held grid companies are. He further mentioned how power-based tariffs would promote the DCB for end consumers as it would help them lower energy costs. Söder pointed out Sala Heby Energi (SHE) as one company that could be of interest regarding DCBs since SHE is municipally-owned and have a power-based tariff model.

Söder also presented the example of how SVK have stated that they will not be able to provide Stockholm with enough energy in the upcoming years as it will take a couple of years for SVK to build new grid lines connected to Stockholm. And with the increased construction of buildings and data centres in Stockholm the electricity demand will increase. This means that the risk for power outages in Stockholm will increase and thus a demand flexibility tool might be of interest for Stockholm's grid owner (Ellevio) so that they at times can manage loads.

Another area that can facilitate a business case for the DCB, according to Söder, is the case of the power reserve. Every year in preparation for winter SVK have a procurement process of a certain amount of energy. For example, if there would be a scenario where the climate in Sweden becomes very cold and the possibility to import energy is limited, certain loads will have to be disconnected. In such cases there are some energy companies that offer to disconnect their customers if in return the company gets paid a certain amount of money. Söder believes that such companies could be interested in DCBs as it could enable them to disconnect loads more efficiently.

Person X mentioned how he thinks demand flexibility will become more integrated into our lives in the future, especially with the emergence of new technologies. With more mobile energy consumption and volatile energy production the necessity for demand flexibility tools will be great. Apart from the fact that he thought that the DCB is a great tool to support demand flexibility activities, he also stated that companies that work within the field of sockets, distribution boards and circuit breakers, such as Schneider and Legrand, are also trying very hard to develop smart electricity products.

Bartusch expressed great need for a device like the DCB which primarily focuses on the possibility to disaggregate, measure and display the energy consumption of each home appliance for the customer. She explained how power-based tariffs may bring about demand flexibility. Based on two studies that she has conducted, one in Sollentuna and one in Sala, it was found that people who have a power-based time-of-use tariff actually change their behaviour for the better and shifted some of their daily load, such as dishwashing and laundry, to off-peak hours. Together with a tool that can visualize the energy consumption, customers might change their attitude even more and be willing to engage more in demand flexibility activities.

Bartusch presented the example of how people do recycling of waste for free, without any economic incentives and therefore she believes that people are capable of shifting their load to off-peak hours too. It will require that information and knowledge about the advantages, is communicated well towards customers so that the next step can be to change their attitudes for positive impact.

#### 4.2.5.4 Perceived Risks and Barriers

The main barrier for entry in the power reserve market and grid market is, according to Söder, the price. He believes the DCB will be too expensive for energy companies to be interested. Another barrier, according to Söder, is related to what he previously mentioned about private held grid companies being too focused on profit to be interested in DCBs, rather than smart energy distribution.

Person X said that the risk of lacking IT-security and hackers could be factors for lower willingness to invest in tools that have insight in private electricity consumption, such as the DCB. He also mentioned how he thinks that most of what the DCB will offer for private households (electricity control) will be integrated directly into future products.

Bartusch addressed the difficulty of changing people's attitude and making them more prone to demand flexibility activities. She said that it takes a long time to change people's attitudes and for customers to be willing to invest in the DCB without economic incentives, their attitudes need to be on the right track.

#### 4.2.6 Homeowners

The following subchapter presents the results from the conducted interviews with homeowners. The results are presented in diagrams with an explanatory description for each diagram. During the interviews, focus was put on which smart home technologies homeowners already own, what homeowners wish they could improve/compliment in their home, their willingness towards being remotely power controlled by their grid owner, which factors they value for home technology as well as other reflections. See Appendix F for the questions that were asked and Appendix G for a summarized table of the given answers.

Amongst the 25 homeowners that were interviewed around 30% were beta testers for Manetos' current heat control product. These beta testers mainly live in villas that have boilers and have more than one person living in the household. The remaining 70% of the interviewees were homeowners, of which more than 20% had direct heating and the rest had alternative ways of house heating, such as different types of heat pumps and domestic heating. *Figure 29* illustrates the number of homeowners who currently have smart technology solutions in their home, as well as what type of technology they own. As can be seen from the diagram the most common home technology is a smart heating system, which is connected to the fact that 30% of the interviewees were Manetos heat control beta testers. Other smart home technologies that were common include smart lightning systems (including

smart plugs), electrical vehicles and smart security systems. Outdoor technology refers to automated awning, sprinkler system and lawn mower.

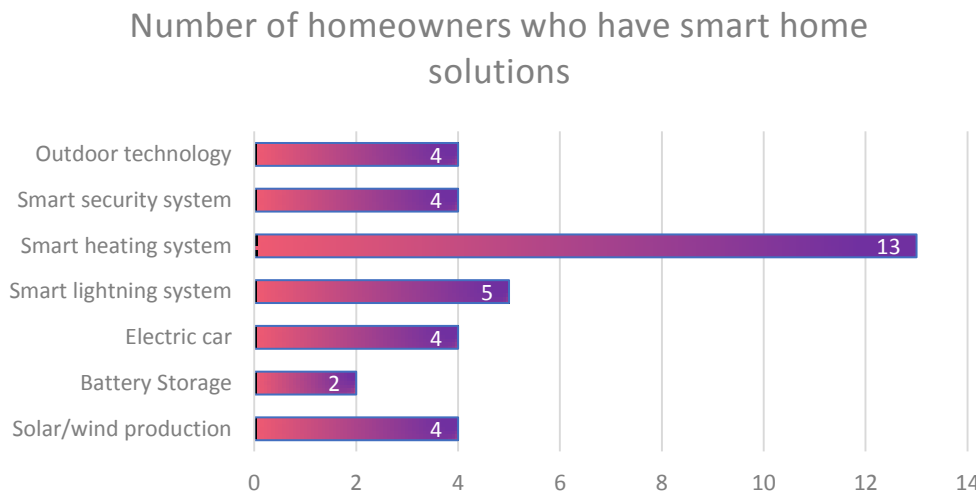


Figure 29. The diagram presents the number of homeowners who own a certain smart home device.

Figure 30 presents homeowners' desired values for smart home solutions. The diagram illustrates how 33% of the homeowners' value comfort and 25% of focus on economic and cost saving solutions. The third biggest desired value was found to be home automation.

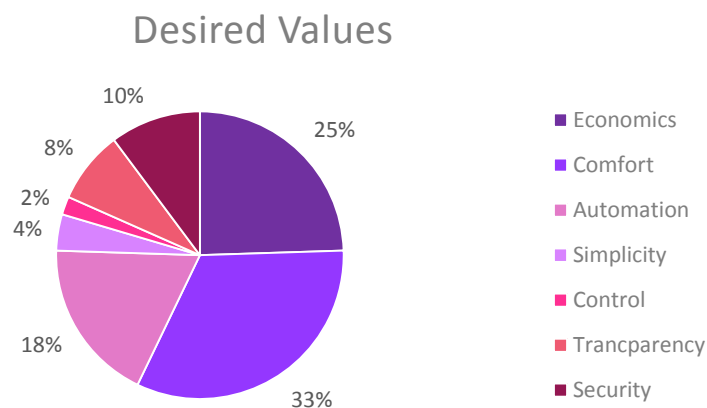


Figure 30. Illustration of homeowners' desired values for smart technology.

An investigated opportunity for the DCBs is to let homeowners monitor and control their own electricity consumption, alternatively allowing the grid owner to manage the controlling. Figure 31 illustrates the rate of willingness, amongst homeowners, to give power control and monitoring responsibility to grid owners. 40% of the interviewees stated that they were only interested in giving up power control if they would benefit from it from an economical perspective, for example by being paid by utilities for allowing grid owners to cut some of their power consumption, i.e. a revenue sharing model. Out of the 25 interviews, 28% answered that they would not give up power control to grid owners. The common reason for this was that they perceived power control by grid owners as "risky" or "an intrusion into

their private lives”. The homeowners which showed low willingness towards power control by the grid owners stated that they would need extra benefits apart from economic incentives. Those who showed high willingness were the homeowners who also showed most interest in the DCB-solution, so called potential early adopters.

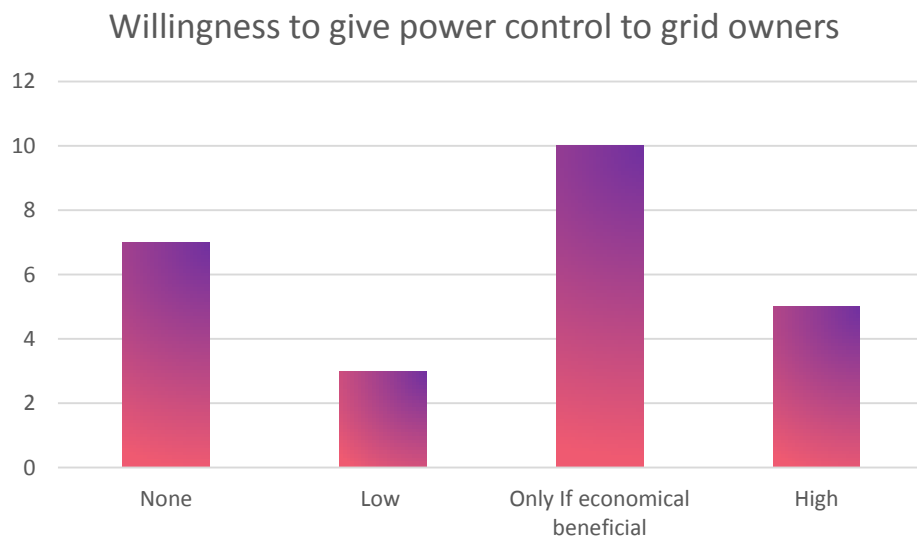


Figure 31. *Illustration of homeowners' willingness to participate in demand flexibility activities through allowing grid owners to manage load.*

## 5. Discussion and Analysis

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*The following chapter presents a discussion and analysis of the empirical findings. The discussion and analysis are based on the conducted interviews and the existing literature that was identified during the literature review. Areas that will be discussed include challenges for the energy market, views on demand side flexibility, different markets' attitude towards the DCB, risks and barriers for the commercialization of DCBs as well as a future outlook of roles and responsibilities on the energy market. The discussion will be analysed from a time-relevance- and economical point of view.*

### 5.1 Investments and Transparency

An opinion shared by the majority of both agencies and utilities is that the current electrical grid is aged, worn out, and in need of refurbishment. One reason for this, based on the conducted interviews, is that energy production today is becoming more volatile and at the same time consumers are consuming energy in an unpredictable manner. Also the development of technologies such as electric vehicles, battery storage and micro production creates new demands for the energy system. Updating the grid requires investment costs which often come from increasing tariffs for end consumers. Based on interviews with homeowners it was concluded that end consumers are not aware of why tariffs increase and what the money that they pay goes towards. We believe that the DCB could become a tool for both managing volatile production and load as well as giving end consumers more transparency into their energy costs and consumption. Despite most utility companies perceiving peak demand as a non-critical issue, many actors spoke about the benefits of shaving these peaks. We believe that for the future, if peaks could be decreased, value could be created and further expansion of the grid avoided. In our opinion the DCB could potentially deliver value to grid companies if it was an equally economically beneficial alternative compared to building new grid lines.

Lennart Söder believed that many of the challenges on the energy market today are rooted in how regulations are constructed. An area which was discussed to be a challenge for the DCB was the revenue cap for grid companies, which covers costs for conducting business and giving a reasonable return on capital necessary for conducting business. The purpose of the revenue cap, which is set by Ei, is that it regulates the size of the electricity tariff which the electrical grid companies are allowed to charge (Energimarknadsinspektionen, 2014b). The issue with this type of revenue cap is, according to Söder, that companies would potentially rather invest in expanding their grid as opposed to investing in smart technology used for peak shaving, as the revenue cap is increased with more connected customers. As costs for investing in new technology or infrastructure, often is placed on consumers through tariffs, our opinion is that possible revenues from investments are what determine which solution for reducing peaks that is to be chosen. If a company is very profit based, such as privately held grid owners, they might choose a solution that generates the highest margins and profits. If a company instead focuses less on profits, and more on their customers, such as municipally owned companies, socioeconomics and low tariffs may be put more into focus. The results of

the interviews with municipally owned grid companies showed that they place large focus on the management of their grids and keeping tariffs low, rather than investing in expansion of the grid.

## 5.2 Tariffs to Increase Demand Side Flexibility

A common view amongst utility companies and energy agencies is that the tariff system for Swedish energy consumption will transition towards power-based and time differentiated tariffs. Based on the conducted interviews, power-based tariffs seem to promote demand side flexibility by increasing economic incentives. Many utility companies and agencies believe that power-based tariffs will work as economic incentives for end consumers to shift their energy consumption to off-peak hours. In Ei's report *Åtgärder för ökad efterfrågefleksibilitet i det svenska elsystemet* (2016a) the agency concludes that tariffs that give incentives to level out uneven power output (load) and shift power output to off-peak hours are positive from an energy efficiency perspective. Based on this Ei conclude in their report, that power-based tariffs will give stronger governance than energy-based tariffs and that it might be beneficial, from a societal perspective, if all customers had time differentiated tariffs. Bearing in mind that demand side flexibility aims to shift energy consumption to off-peak hours and thereby evening out the load on the grid, we believe that power-based tariffs could be a potentially important driver for end consumers wanting to invest in DCBs.

Bartusch & Wallin et al. (2011) discuss the importance of increased demand side flexibility to fully exploit the Swedish power system and reach political goals related to energy efficiency and climate change. Even so, the number of demand side flexibility programs for Sweden's residential sector are few and one reason for this, according to the authors, is the lack of information about what the gains of demand side flexibility are. In their study, Bartusch & Wallin et al. (2011) study customers' perception of a demand-based time-of-use electricity distribution tariff and the results show that households have a high opinion of the demand-based tariff and act on its intrinsic price signals by decreasing their consumption in peak hours and shifting electricity usage from peak hours to off-peak hours. The households that participated in the study showed a sympathetic view on being charged based on demand-based tariffs when the distribution operator's motive for introducing the tariffs was that it relates to environmental issues. We believe that this shows how people to some degree shape their behaviour and habits in line with their own values, ethics and moral and not only through economical gains. This could also be seen through the conducted interviews as the majority of actors, despite which market segment they belonged to, spoke of how consumers are becoming more energy conscious. In line with this is the example that Bartusch presented, during the interview, regarding how many people in Sweden recycle without any economic incentives, but rather for the environment and the sake of future generations.

## 5.3 Perceived Attitude Towards the DCB

Presented below is an analysis of each interviewed market segments' perception of the DCB. The analysis and discussion has been conducted based on the study's empirical results and discussion.

### 5.3.1 Homeowners

During the interview with Bartusch, the case of changing people's attitude was discussed. Bartusch mentioned how economic incentives alone cannot motivate customers to change their electricity usage habits, however a need for impacting their attitudes exists. Changing attitudes is time consuming, according to Bartusch, and in order to succeed with this there is a need for better transparency, information and knowledge sharing as well as something Bartusch refers to as divided feedback (in Swedish: "uppdelningsåterkoppling") of energy consumption. We believe that there can exist a case here where DCBs can fill many of the functions needed in order for people to change their attitudes and behaviour towards electricity consumption. If the DCB can deliver transparency and divided feedback of energy consumption, which is what the agencies wish to achieve with power-based tariffs and demand side flexibility, then there is potential for the DCB to deliver value for utility companies.

It is important, however, that end consumers want to use DCB for demand side flexibility purposes. In order for them to consider DCBs, the value offering must be precise. When analysing how homeowners positioned themselves towards DCBs we identified two prioritised factors which they look towards, namely economical gains and comfort in their home. Based on the above discussion regarding changing peoples' attitudes and how, the economical aspect might be less important in the future, it is concluded that comfort will remain central. The DCB can deliver both comfort and economical gains, but in most cases this will entail that homeowners have to perform the electricity monitoring themselves, since 50% of the interviewees showed low willingness to let someone else (e.g. the grid owners) monitor their electricity consumption. In order for them to allow someone else to monitor their electrical devices there needs to exist bigger economic benefits than what can be gained with today's low electricity prices. For those who showed high willingness to allow grid owners to control and monitor electricity consumption in their home, the motive was also related to economic gains (for those with direct heating) or it was related to pure tech interest or an urge to help society and the grid to function better. An interesting aspect from the interviews with homeowners was that all households which owned an electric vehicle could imagine a DCB to monitor and control the charging process.

Based on the interviews with homeowners we identified a need for an automatic charging solution where electric vehicles are charged when the electricity price/demand is low and where the car is disconnected when the electricity price/demand is high. We also believe that the DCB will do better off in a first scenario if homeowners can control and monitor their electricity themselves or automating it, rather than letting grid owners control their electricity consumption. In some way, the DCB would work as an information/transparency tool for homeowners and this goes in line with Bartusch's study (Bartusch, Visualisering av elanvändning i flerbostadshus, 2009) where it was found that divided feedback on energy consumption is a good tool for guiding homeowners towards energy efficiency activities in their home. We believe that the DCB could help inform people of their electricity consumption and so favouring the attitude change needed in order for demand side response

to become successful. According to the interviews at E.ON and Ellevio, grid owners will only become interested in DCBs when the user volume of homeowners is large enough to show a profitable case.

By analysing how the DCB meets homeowners' criteria from a *time*-perspective, we believe that the DCBs will help homeowners to save time by allowing remote control of appliances. However, time can potentially be negatively impacted if the DCB is used as a demand side flexibility tool, requiring that homeowners plan their daily activities according to times of peak demand. We believe that the *time* aspect is of “medium” importance to homeowners, see *Figure 32*, meaning that they do care about how their time is affected, but not enough not to be interested in the DCB. From a relevance point of view, we believe that the DCB highly meets the needs of homeowners. Based on the discussion above and the empirical results we can see that homeowners are very value driven. They desire better comfort, smarter security systems and more automatized functions in their homes. For these reasons, we have classified the *relevance* of the DCB as “high” for homeowners, see *Figure 32*. Based on the interviews we can also see that *economics* play a significant role in whether homeowners are willing to invest in smart technology or allow grid owners to control their power as part of demand side flexibility. Therefore, *economics* is classified as “high”, see *Figure 32*.

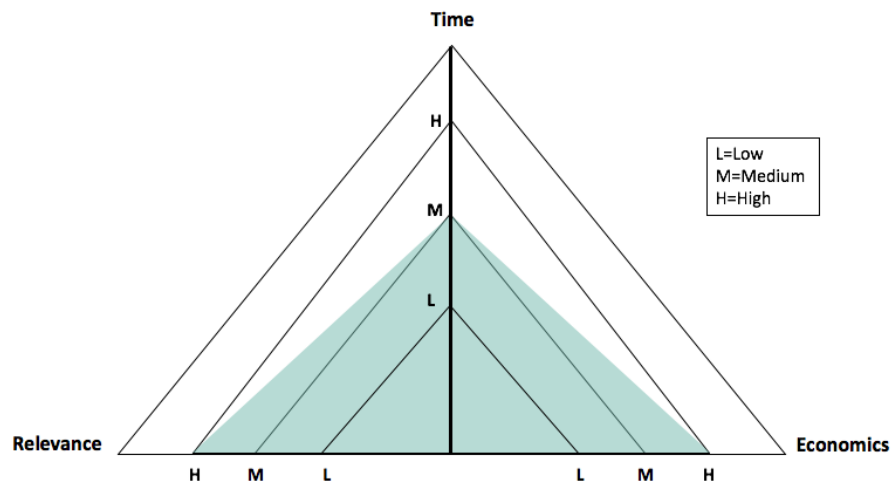


Figure 32. Illustration of how the DCB meets homeowners' needs from a time-, relevance- economics- point of view.



### 5.3.2 Utilities

All actors on the electricity market, i.e. utilities, as well as agencies and the interviewed experts agreed that the integration of more intermittent and volatile energy sources is a significant challenge for the future energy system. Ei describe in their report *Ökad andel variabel elproduktion – effekter på priser och producenters investerings incitament* (2016c) how in order to handle climate change the electricity production needs to become emission free and expand the amount of renewable energy production. The increased amount of variable and renewable energy production will create new demands for the electricity market and its players (Energimarknadsinspektionen, 2016c).

We believe that the DCB could become an important tool in order to facilitate the integration of more intermittent and renewable energy in the energy system, through incorporating more flexibility and engagement from consumers. When speaking of the challenge of intermittent energy many of the interviewed actors, both utilities and agencies, suggested demand side flexibility as a solution to the problem. In the collaborate report *Challenges and opportunities for the Nordic power system* (2016) by The Nordic TSOs, Statnett, Energinet DK, SVK and Fingrid, it was presented how intermittent renewable energy production is a main driver for increasing demand flexibility and that the location of the new renewable energy generation has a significant impact on the design and refurbishment of the current electrical system. Ei also discuss in the report *An electricity market in transition* (2014) how more renewable energy increases the demand for flexibility in form of balancing and regulation power. Ei furthermore, discuss in their report *Efterfrågefleksibilitet – en outnyttjad resurs i kraftsystemet* (2017) how demand side flexibility will contribute to maintaining stable frequency on the grid, which will be of great importance as renewables increase the efforts needed to maintain frequency.

A common view seems to be that action must be taken in order to manage the integration of intermittent energy, and the attitudes towards demand side flexibility are seen as positive. During interviews with utilities and agencies it was discussed how smart control instruments, which promote electrical and economic governance are needed. However, there seems to be a lack of these types of control instruments and we believe that the DCB could be a solution which is flexible and efficient in managing load. From a utility point of view, the perception was that intermittent energy was believed to have the largest impact on local grids. The local grid problems will potentially increase with the development of electric vehicles, micro production and battery storage, which all create needs for refurbishment and expansion of the current grids. An alternative to investing in the grid, entailing costs which often are placed on customers through tariffs, could be to harness demand side flexibility through DCBs. Ei has a similar view on the necessity for demand side flexibility for local grids, meaning that it could contribute with more efficient grid usage which decreases network losses, costs for overhead grids and the need for investments in form of new capacity on the grid (Energimarknadsinspektionen, 2016a).

Maintaining balance between production and consumption, and keeping transmission losses low, are issues which may increase when integrating more renewable energy in the energy system. As the amount of base power potentially decreases, flexible regulation power is required for when intermittent energy sources do not deliver enough energy. Ei's representative discussed how Sweden has a large amount of hydropower which today amounts to enough in order to cover the Swedish energy need. According to Ei (2014a) hydro power has allowed Sweden to increase the amount of intermittent energy, however the flexibility which hydropower offers is limited. And as the rest of Europe transitions more towards intermittent energy sources the need for export of regulation power will increase (Energimarknadsinspektionen, 2014a). Person X, however, discussed how Australia, when integrating more volatile energy sources in their energy system, shut down many of their coal plants. When shortages in energy then occurred, gas turbines had to be operated, which were more expensive than coal. We believe that the DCB could become a tool that can ease the transformation towards more renewable energy, especially in the early stages when power shortages may occur more often. A reconstruction of the grid will according to SVK temporarily jeopardize the operational security and an efficient market in the coming decade due to intermittently limited capacity (The Nordic TSOs, 2016)

When analysing how the DCB meets utility companies' criteria from a *time- relevance- and economical-* point of view we see that the outcome differs somewhat between municipally owned utilities and privately held utilities, see *Figure 33 & Figure 34*. This is based on the discussion above, about municipally owned utilities being much more focused on service and cost reducing activities towards their customers and not as profit focused as privately held companies. That is why the *economic* aspect is set as "high" for private utility companies and "low" for municipally owned utilities. From a *relevance* point of view, we believe that the DCBs' potential for demand flexibility will be welcomed faster by municipally owned utilities since they want better service and overall costs for their customers to decrease. Privately

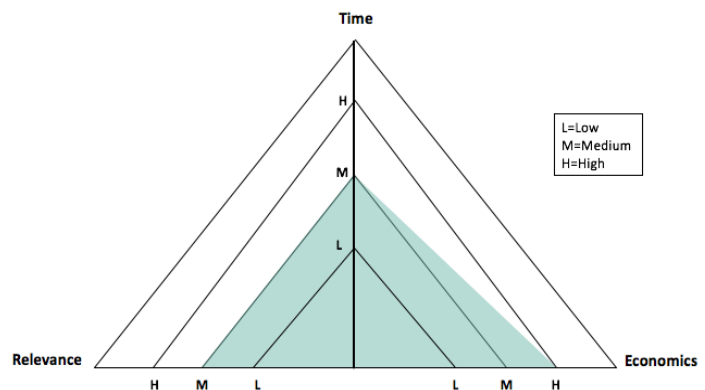


Figure 33. Illustration of how the DCB meets privately held utility companies' needs from a time-, relevance- and economic- point of view.

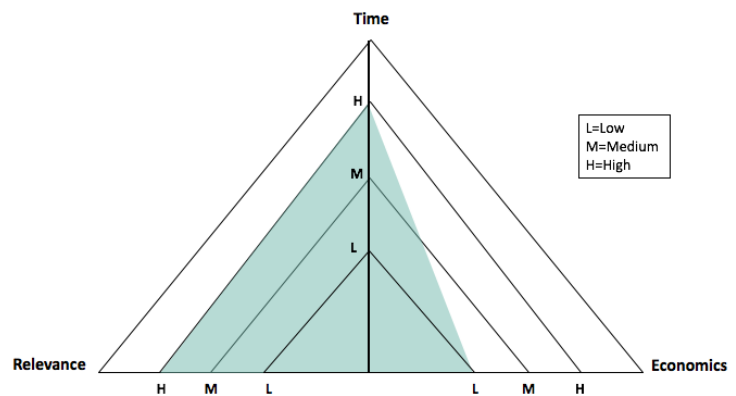


Figure 34. Illustration of how the DCB meets municipally owned utility companies' needs from a time-, relevance- and economic- point of view.

held utilities on the other hand always weigh whether investment costs can be transferred to their customers' fees, while still being somewhat interested in demand side flexibility tools for their customers. Therefore, *relevance* has been classified as “high” for municipally owned utilities and “medium” for privately held utilities. From a *time*-perspective we believe that municipally owned utilities have the potential to do more work in less time since they often cover smaller areas than privately held utilities. Furthermore, our perception is that privately held companies do not, in general, prioritise time as highly as municipally owned companies since they have many more stakeholders involved in their decision-making processes, while municipally owned companies are practically only owned and affected by the people living in the municipal. Therefore, we believe that municipally owned companies work to achieve goals faster and thus time is of greater importance for the than for privately held companies, see *Figure 33 & Figure 34*.

### 5.3.3 Real Estate Companies

Concerning real estate companies, the common perception was that the DCB could work as a good reviewing and monitoring device, however Akademiska Hus did not seem interested in using the DCBs for control since they conduct most of their control and troubleshooting manually for safety reasons. Vectura did, on the other hand, see great potential to use DCBs as a monitoring tool, especially in the future when buildings become more automated and smart. When comparing the two real estate companies we noticed that the needs and attitudes towards the DCB differed a lot. This might relate to the fact that Akademiska Hus and Vectura specialise in two very different real estate types.

Akademiska Hus owns research facilities and buildings on different university campuses in Sweden, while Vectura mostly own office-buildings and elderly homes. The needs are different for different types of buildings and in Vectura's case, the need to monitor comfort for elderly homes and the need to have energy efficient office buildings is a clearly stated goal. Akademiska Hus, on the other hand, already feel that they have enough control over their buildings' energy consumption. The reason for this could be that the electricity costs are covered by the tenants and not Akademiska Hus. They do, however, aspire to engage their tenants to become more conscious about the way they handle electricity. In this case, Akademiska Hus could use DCBs as an informative- and transparency tool for their tenants. We believe that there is potential for DCBs to become a helpful tool for real estate owners, but this market segment needs to be furthered studied and analysed through more interviews with a variety of real estate companies.

From a time-, relevance- and economical point of view we believe that the DCB can be very successful in regards of relevance since it allows for functions like remote control, remote monitoring and security of buildings, which are all very relevant and of interest for real estate owners. Thus, relevance is set classified as “high” in *Figure 35*. As for the economical dimension, we believe that real estate companies do not think of electricity as a heavy cost burden since electricity costs, often, are placed on tenants. However, real estate companies do try to aspire for less energy consumption by engaging their tenants in smarter energy

consumption and by having smarter ventilation systems and sensor lights. We also believe that they would favour solutions that save time, for example a solution that allows for troubleshooting and correction of errors remotely/digitally. This would entail fewer site visits and thus saving time. Therefore, we believe that time should be classified as “medium” with regards to the potential time-saving solutions the DCBs could provide.

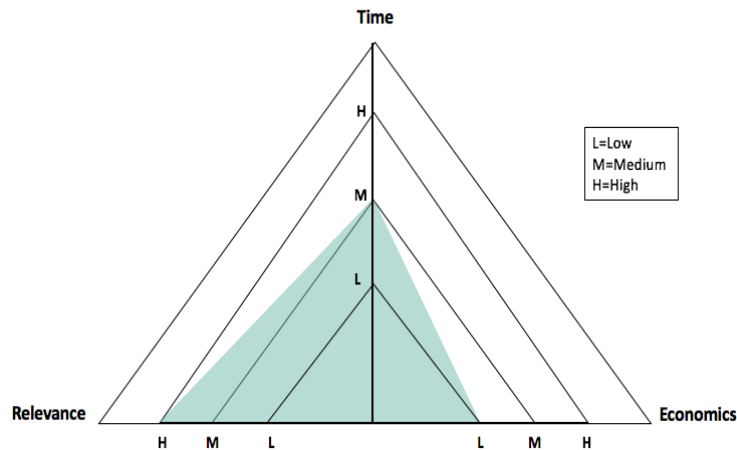


Figure 35. Illustration of how the DCB meets real estate companies' needs from a time-, relevance-, and economical point of view.

### 5.3.4 Electricity Retailers

Amongst the electricity retailers the perceived interest for the DCB was deemed to be low. The challenges and issues that the electricity retailers presented regarding their business were associated with the high competition on the market as well as how to package value towards customers in order to stand out from the competition. The retailers were also facing a change in responsibility as they in the future are going to be the main contact for customers, due to the customer centric business model that is being introduced. Our perception of the situation is that the DCB cannot create great value for the retailers' business, as many of the issues that the DCB can solve do not fall within the retailers' business area, such as peak shaving, managing loads etc. However, we believe that the DCB could work as a tool for creating more value for the electricity retailers' customers. If the retailer were to offer a DCB service to customers it could signal that they want to have an active relationship with their customers and that they want them to consume energy in a smart way as well as show that they care about sustainability and the environment. Both interviewed retailers also pointed out how customers are becoming more energy conscious and consume according to their values, therefore offering the DCB to their customers could increase loyalty and create a competitive advantage for the energy retailers.

When analysing the DCB for electricity retailers from a *time-, relevance- and economical* perspective all factors have been classified as “low”, see *Figure 36*. As has been discussed above, and which can be seen from the conducted interviews, the relevance of the DCB for electricity retailers is limited. As the issues that the DCB solves do not fall within the retailers' main responsibilities, as well as many of the retailers' problems being connected to

competition and value creation, the *relevance* perspective is “low”. The *time* perspective is also “low”, if the DCB were to be offered from electricity retailers it would most likely be an add on value service to their customers, which would entail more time and effort being required from the retailers. Furthermore, as the DCB is meant to be a demand side flexibility tool, meaning that it wants to reduce energy use, the *economical* perspective is deemed “low” as it most likely would entail less energy being sold. However, an interesting aspect to consider is that certain companies are engaged in projects which promote energy saving solutions, such as Bixia who take part in solar energy projects today. These projects may decrease the amount of sold energy, however, it creates value for customers and strengthens the brand experience.

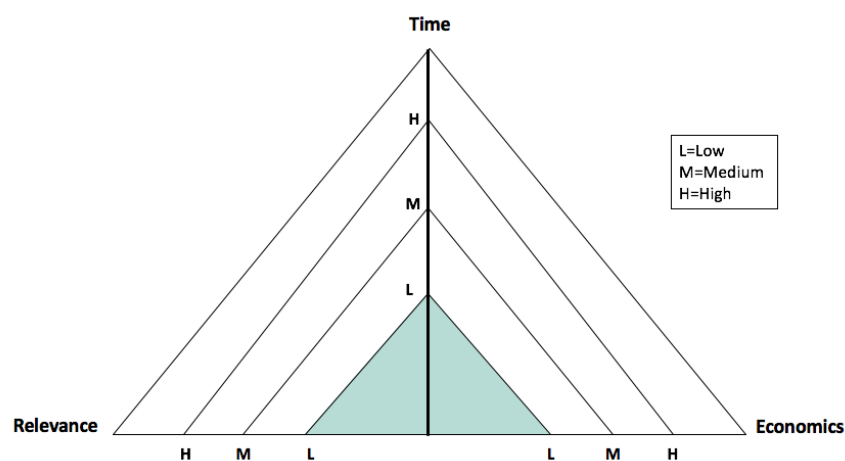


Figure 36. Illustration of how the DCB meets electrical retailers’ needs from a time-, relevance, and economical point of view.

## 5.4 Roles and Responsibility

Challenges regarding actors’ roles and responsibilities on the electrical market was a common trend throughout the interviews with agencies and utilities. What can be concluded from the interviews and existing literature, is that many of the different roles on the electricity market are developing and including new responsibilities. Swedish Smart Grid focused a lot on the EU’s Clean Energy for Consumers package, which is an attempt to create a common energy union in Europe. The package was presented in 2016 and negotiations will be finished in 2017, with the goal of putting energy efficiency first, achieving global leadership in renewable energies as well as providing fair deals for consumers (European Commission, 2016a).

The Clean Energy for Consumers package also includes how the role of the grid owner should be established in the future. Swedish Smart Grid’s representative emphasized how the design of the grid owner role has a significant impact on the electricity market. If the grid owner’s responsibilities remain unchanged, new technology will be left to face a competitive market, allowing for new business opportunities to emerge. Should the responsibilities of the grid owner increase, and include for example energy storage, their monopolistic position and

power will increase. Energikommisionen discuss in their report *Marknadsdesign för framtidens energisystem* (2016) that an expansion of the grid owner role for regional and local grids would facilitate demand side flexibility for power control and more efficient grid maintenance. Energikommisionen further emphasize that the development of the grid owner role can be expanded for regional and local grids without negatively impacting the separation between grid operations and market activities (Energikommisionen, 2016). The different roles and responsibilities on the electricity market can impact which stakeholders that are seen as attractive customers for the DCB or which market segments that are perceived as most viable. Therefore, we believe that it is important to investigate and learn how the energy market and the different roles will develop during the implementation of the Clean Energy for Consumers package.

## 5.5 Barriers for Implementation of the DCB

Based on interviews and the conducted literature study, we have come to understand that the energy market is heavily regulated both from national authorities and EU-authorities. For DCBs to be implemented there are certain regulations that need to be considered, especially in aspects of how these regulations affect the commercialization of the DCB. One reform that we believe will be important to look over when setting a business plan for the DCB is the new EU Data Protection Reform, which is to be applied no later than 25 May 2018 (European Commission, 2016b). The causes for this new data protection reform are many, but one reason is to better protect personal data that flows cross-border between public and private actors (Datainspektionen, 2016). Another reason is given as:

“Rapid technological developments and globalization have brought new challenges for the protection of personal data. The scale of the collection and sharing of personal data has increased significantly. Technology allows both private companies and public authorities to make use of personal data on an unprecedented scale in order to pursue their activities. Natural persons increasingly make personal information available publicly and globally. Technology has transformed both the economy and social life, and should further facilitate the free flow of personal data within the Union and the transfer to third countries and international organizations, while ensuring a high level of the protection of personal data.” (Datainspektionen, 2016)

From this extract we can see that the European Commission has recognized the fast paced technological advancements that are happening in the near future, and we believe they see this rapid advancement as a threat towards data usage. Therefore, it is utterly important that the DCB follows the new data reform, since the DCB will extract valuable information of homeowners' electricity usage. From the data information the DCBs can extract, conclusions can be drawn about homeowners living patterns and vacation patterns which may be perceived as integrity trespassing.

During the interview with Swedish Smart Grid information emerged regarding grid owners not having rights to collect energy consumption data past the metering box. The metering box is positioned outside the houses, and Swedish Smart Grid said that grid owners do not have the right to go past the metering box and collect data from inside the houses. If they were to do so, the Personal Data Act (PUL - personuppgiftslagen) has to be applied. If homeowners were to allow grid owners to control their electricity usage, the need for agreements and contracts between homeowners and grid owners is crucial, where the agreements clearly state how gathered data is to be used and how personal information is handled. We believe that this type of agreement can be perceived as “risky” by homeowners and as a “strenuous responsibility” for grid owners. Together with the implementation of the EU Data Protection Reform (European Commission, 2016b) this can present a bigger challenge than initially believed. We would recommend to further investigate this area with help of a business lawyer specified on the energy market’s regulations.

The matter of product liability is also an important aspect to consider when developing the DCB. What happens in a home appliance, such as the laundry machine, breaks down? Can the customer be guaranteed that the DCB is not the cause for the break down? Swedac is the Swedish National Electrical Safety Board (Elsäkerhetsverket) which is responsible for safety regarding electricity in Sweden (Swedac, 2017). They are responsible for certifying products, which is something the DCB will have to undergo before it can be commercialized. Therefore, it is essential that there are no safety issues with the DCB.

Regardless, we believe it is important to consider potential cost-related risks that come with an electricity monitoring tool, such as the DCB. The functionality of the DCB must be communicated clearly so that each user of the DCB knows about its capabilities and risks. If grid owners were to be responsible of installation and monitoring of DCBs for their customers, then the risk of product liability might lay on the grid owner. This could add to the list of “strenuous responsibility areas”, which would chase away grid owners as a potential partner. Bearing all this in mind, the packaging of DCB towards each customer segment must be processed carefully.





## 6. Conclusions

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*Based on the discussion and analysis, the following chapter presents a summary of the conclusions drawn. The conclusions presented will provide answers to the research questions that were set in the introduction. Furthermore, this chapter will present recommendations for further research that has been identified as necessary.*

The purpose of the following research was to investigate potential business markets for the DCB in Sweden. The following research questions have been answered:

- What are potential viable business markets for DCBs?
- What challenges and future trends do customers in each market face?
- What driving factors will facilitate vs. impede the commercialization of the DCB?

### 6.1 Answering the Research Questions

The potential markets which have been investigated for the DCB in this study include electric utilities, real estate companies, electricity retailers and homeowners. The conducted interviews show that the need for an electricity monitoring tool is greatest within the utility-sector. The grid today is in need of solutions which can handle the numerous challenges that it is facing, such as uneven load, increased integration of intermittent energy, old grid lines, shifts in actors' roles and responsibilities as well as unpredictable consumption. The study showed that utility companies value demand flexibility tools as more intermittent energy and electrical vehicles put more pressure on flexible capacity on the grid. When dividing utility companies into categories of private and municipally owned, the study found that local, municipally owned utility companies were more prone towards investing in the DCB as a demand flexibility tool. The municipally owned companies focused more on socioeconomics rather than being profit based in comparison to the privately owned companies. The privately held companies on the other hand, instead focused more on refurbishment and restoration of their current grid network.

As demand side flexibility was a reoccurring topic amongst utility companies and agencies, homeowners too were questioned about demand side flexibility, as they are a significant player in demand flexibility activities. The study showed that homeowners with electric vehicles showed the largest interest in the DCB as they were searching for solutions that allowed them to charge their vehicles when electricity prices were low, both as cost saver but also in order to help with levelling load on the grid. Common amongst the homeowners was that they valued comfort and home automation. The study also found that homeowners are becoming more aware of their energy consumption, creating an interest in energy management technologies such as the DCB. However, not many of the interviewed homeowners perceived the need for lowering energy costs as being important enough to take significant action today, since the electricity prices today are low. This opinion was also shared by the electric utilities, who believed that the economic incentives for investing in a technology such as the DCB were too small with current electricity prices.

Power-based tariffs became an important part of the study when investigating which factors that have an impact on people’s behaviour regarding electricity consumption. The study found that power tariffs had a big impact on energy costs during peak hours. This means that power tariffs could work as economic incentives for homeowners to better manage their electricity usage and reduce their electricity costs. It was found that homeowners who currently had a power-based tariff were more conscious of their energy consumption than the homeowners who had an energy-based tariff. For grid owners, power-based tariffs would contribute to lowering the extracted power and avoid peaks in demand. Therefore, it was concluded that power-based tariffs speak in favour for the DCB.

Regarding real estate companies and energy retailers, a larger amount of interviews must be conducted in order to achieve a fair representation of the sector. The general analysis conducted on the real estate sector showed that the market is interesting enough for further studies. Real estate companies are looking for ways to make their buildings more energy efficient, to achieve better control for managing the energy in their buildings as well as to make their tenants more energy conscious. Energy retailers, on the other hand did not show much interest in the DCB as their focus area lies elsewhere and not on producing and distributing energy.

Bearing all this in mind, a conclusion about municipally owned utility companies being a viable market segment can be drawn. Furthermore, the greatest potential is shown to be municipally owned grid companies that have a power tariff already in place, since their customers are well adapted to thinking consciously about electricity costs and consumption. Another viable market identified is homeowners who have direct electricity heating and homeowners who own electrical vehicles. *Figure 37* illustrates the main conclusions draw regarding current viable markets.

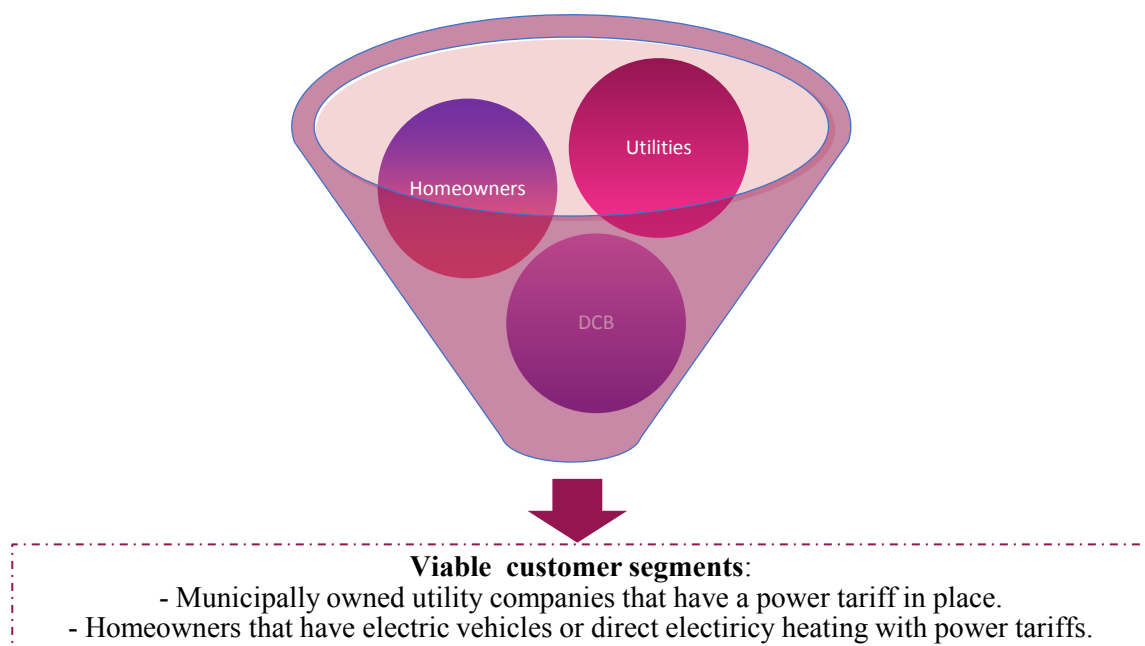


Figure 37. *Viable customer segments within the utility- and homeowner- sector.*

For the future, however, it is important to remember that the electricity market will undergo a lot of development, which has been covered in this study, and thereby give rise to new viable customer segments. We believe that there will be great potential for a technology such as the DCB in the near future in more customer segments than the two presented above. By year 2024 we believe that people's interest in smart home technology will have increased as well as the demand for smarter monitoring technology from both utilities (including privately owned) and from real estate companies. *Figure 38* presents a summary of why we believe that real estate companies, privately held utility companies and homeowners will be viable markets for the DCB in the future.

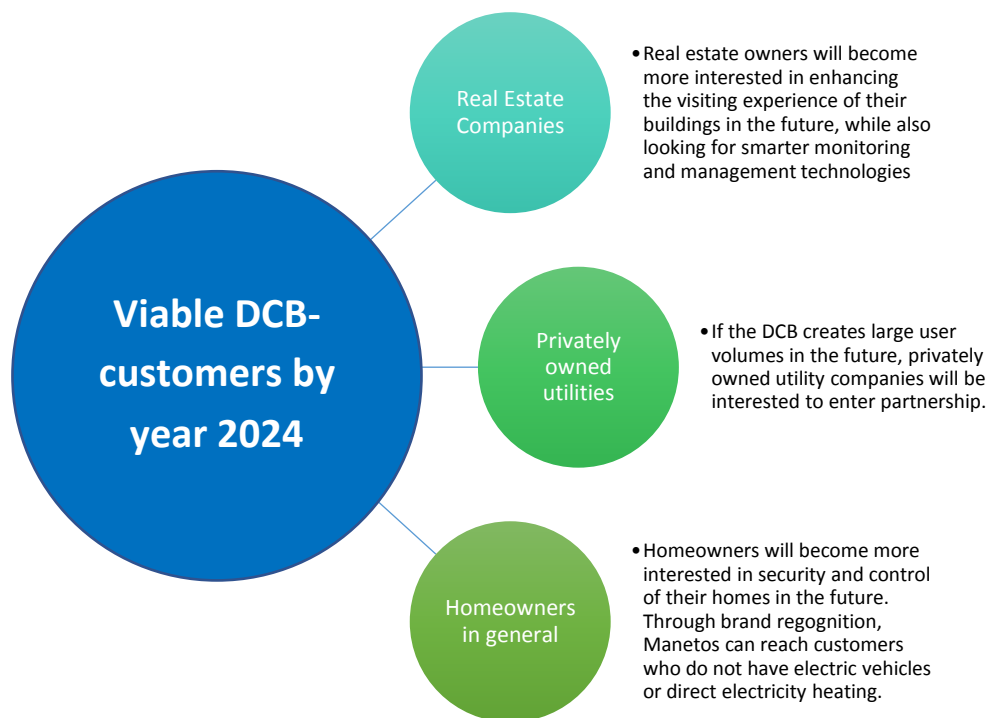


Figure 38. *Potential customer segments for the future (year 2024).*

## 6.2 Future Research

As the DCB is a new technology, which has not yet been introduced to the market the areas in which further studies can be made are many. The purpose of this study was to investigate potential business markets for the DCB in Sweden. However, further studies regarding the identified markets as well as how the DCB should be commercialized and packaged are of interest. Presented below are suggestions for further studies for the DCB.

- In this study the market segment for real estate companies was touched upon briefly and found to be of interest. Therefore, further research within this segment is recommended. The two interviews with real estate companies in this study showed that one of the actors was sceptical towards the DCB, mainly from a safety perspective. However, the other actor showed great interest towards the possibility of monitoring and managing the electricity consumption in their buildings. Especially bearing in mind, the types of buildings that they owned, such as offices and homes for the elderly. We recommend that more interviews with real estate companies should be made in order to see if their opinion towards the DCB matches with the opinions found in this study, and to see if the market for real estate owners is viable.
- A larger group of home owners should also be interviewed in order to achieve a better view of the population's opinions. Including a larger selection of home owners that have direct electrical heating would be of interest as their electricity consumption often is larger. Furthermore, it would be of interest to interview home owners who live outside of the Stockholm area to see if the geographical location has impact on the results.
- Finally, studying potential markets from an international perspective is recommended. Many other countries have a larger amount of direct electric heating than in Sweden as well as different energy infrastructure and resources. This may have an impact on the potential viable markets and opinions towards the DCB, which makes it interesting to further investigate.

## 7. Appendices

The following chapter presents all the appendices referred to in the study, i.e. Appendix A - Appendix G.

### 7.1 Appendix A

The table below presents a brief introduction of each company and expert/researcher that was interviewed in this study. For details regarding the interview questions, see Appendix A-D.

<b>Company Expert/Researcher</b>	<b>Background Information</b>
Vattenfall	Vattenfall is one of Europe's largest heat and electricity distributors and one of the largest heat producers. Vattenfall's main markets are Denmark, Finland, the Netherlands, Germany, Great Britain and Sweden. The group has approx. 20,000 employees and the parent company Vattenfall AB is wholly owned by the Swedish government (Vattenfall, 2017c).
Ellevio	Ellevio's business includes owning, operating and developing regional and local grids which reach 918 000 customers in Sweden. The majority of customers are based in Stockholm whereas the majority of the grids are located on the countryside. (Ellevio, 2017)
E.ON	E.ON produces and delivers energy to the Nordic market in form of electricity, gas, heating, cooling, waste management and energy associated services. E.ON have approximately one million customers. (E.ON, 2017)
Sala Heby Energi	Sala Heby Energi is a municipally owned energy and environment group, owned by the municipals Sala and Heby. Sala Heby Energi has four main business areas; electricity trading, heating, electrical grids and energy efficiency. (Sala Heby Energi, 2015)
Sollentuna Energi och Miljö	Sollentuna Energi och Miljö is a municipally owned energy and environmental company. The company has six main business areas; city networks, electricity trading, electrical grids, district heating, waste and water. (Sollentuna Energi och Miljö, 2017)
Svenska Kraftnät	Svenska Kraftnät is the agency which is responsible for making sure that the electricity transmission system is safe, environmentally adapted and cost efficient. Svenska Kraftnät monitor the electrical system as well as build new grid lines in order to meet future electricity demand. (Svenska Kraftnät, 2017)

Fortum – Charge and Drive	Fortum Charge and Drive is the part of Fortum which works with electric vehicles and charging stations. The Fortum group are a leading company within clean energy with 62% of the energy production being CO <sub>2</sub> -free. In the Nordics Fortum has 1,3 million customers, of which 50% are located in Sweden. (Fortum, 2017)
Energimarknadsinspektionen	Energimarknadsinspektionen is a regulator which works on behalf of the Swedish government. Ei's responsibilities include working for well-functioning energy markets. They supervise and develop the rules and regulations for the electricity-, district heating- and natural gas-markets. (Energimarknadsinspektionen, 2012)
Swedish Smartgrid	Swedish Smartgrid is a forum for smart grids assigned by the Swedish government. The forum's focus is to develop the dialog regarding the potential for smart grids as well as develop a national strategy in order to facilitate smart grids as a growth sector on a global market. (Swedish Smartgrid, 2017b)
GodEL	GodEl is an electricity retailer which only offers variable electricity prices and only delivers 100% renewable energy that is "Bra Miljöval" certified. GodEl has been selected as Sweden's most sustainable electricity retailer 7 years in a row by Sustainable Brand Index and is classified as one of Sweden's top 15 most sustainable brands. (GodEl, 2017)
Bixia	Bixia is owned by seven regional companies and the company focuses on diversity through offering electricity from many local energy producers of renewable energy. Bixia have had power trade on Nord Pool since 1999. (Bixia, 2017)
Akademiska Hus	Akademiska Hus is one of Sweden's largest real estate companies which build, develop and manage buildings. Their buildings are located all over Sweden, however the majority of the buildings are universities and colleges. (Akademiska Hus, 2017)
Vectura	Vectura is a real estate company which focuses on a small selection of building segments; namely social buildings, offices and hotels. It is a young company which was founded in 2012 and which focuses in long term ownership. Their business focuses on developing, managing and owning sustainable and innovative real estate solutions. (Vectura Fastigheter, 2017)

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Lennart Söder, KTH	Lennart Söder is a professor in Electric Power Systems at KTH and is engaged in research and education within the field of Electric Power Systems. (KTH, 2017)
Cajsa Bartusch, Uppsala Universitet	Cajsa Bartusch is a researcher within market based control means on the electricity market. Her research primarily aims at making energy usage more efficient from a system perspective by decreasing demand when there are limits in the capacity for distribution and production. (Uppsala Univeristet, 2017)

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## 7.2 Appendix B

During interviews with agencies a semi-structured approach was used. Below are the standard questions that were asked. The same questions were asked in all interviews. Based on the answers that were given to these questions, follow-up questions were asked. These follow-up questions are not included below.

1. What is your role in the energy market?
2. What challenges does the energy market face today and in the future?
3. What trends do you see for the future electricity system?
4. How do you, as a governmental agency, work toward the existing challenges and towards future developments?
5. How can Sweden achieve a sustainable energy market, with focus on distribution?
6. What is your outlook on the digital development for the electricity system in Sweden?
7. What are the latest news regarding Big Data and IoT for the energy system (possibilities, risks, hinders)?
8. What are your thoughts about the DCB? (advantages, disadvantages, barriers, risks)



### 7.3 Appendix C

During interviews with utilities a semi-structured approach was used. Below are the standard questions that were asked. The same questions were asked in all interviews. Based on the answers that were given to these questions, follow-up questions were asked. These follow-up questions are not included below.

1. What is your role on the energy market?
2. How do you operate?
3. What does your business model look like (including tariff-models and cost regulation)?
4. What challenges do you and your industry face?
5. How do you work with solving these challenges today?
6. How does overloaded grids affect you?
7. How does politics and regulations affect you?
8. What future trends do you see for the energy market?
9. What are your thoughts on the DCB (advantages, disadvantages, barriers, risks)?
10. How do you think the DCB could be incorporated into your company's business towards end-users?

## 7.4 Appendix D

During interviews with energy retailers a semi-structured approach was used. Below are the standard questions that were asked. The same questions were asked in all interviews. Based on the answers that were given to these questions, follow-up questions were asked. These follow-up questions are not included below.

1. What is your role on the energy market?
2. How do you operate?
3. What does your business model look like (including tariff-models and cost regulation)?
4. What challenges do you and your industry face?
5. How do you work with solving these challenges today?
6. What future trends do you see for your industry?
7. How do power peaks on the grid affect you?
8. What are your thoughts on the DCB (advantages, disadvantages, barriers, risks)?
9. How do you think the DCB could be incorporated into your company's business towards end-users?

## 7.5 Appendix E

During interviews with real estate companies a semi-structured approach was used. Below are the standard questions that were asked. The same questions were asked in all interviews. Based on the answers that were given to these questions, follow-up questions were asked. These follow-up questions are not included below.

1. What kind of buildings do you own and operate?
2. What challenges does your company face regarding electricity usage, construction, installation and monitoring of buildings?
3. How do you work with solving these challenges?
4. How much do you work with optimizing energy/electricity usage in your buildings?
5. What trends do you see in electricity consumption (is it increasing/decreasing, if so why)?
6. What future trends do you see in your industry?
7. What are your biggest needs?
8. What are your thoughts on the DCB (advantages, disadvantages, barriers, risks)?
9. How do you think the DCB could be incorporated into your company's business?

## 7.6 Appendix F

During interviews with homeowners a semi-structured approach was used. Below are the standard questions that were asked. The same questions were asked in all interviews. Based on the answers that were given to these questions, follow-up questions were asked. These follow-up questions are not included below.

1. What smart technologies do you currently have incorporated in your home?
2. What home improvements do you desire?
3. What are your thoughts about the DCB?
4. How do you feel about letting your grid owner control some of your electricity load?
5. What are the most important values you seek in smart technology for your home?

## 7.7 Appendix G

The table below summarizes the answers from the interviews that were conducted with 25 different homeowners.

	<b>Current smart home solutions</b>	<b>Desired home solutions</b>	<b>Willingness towards external power control</b>	<b>Desired values</b>	<b>Other reflections</b>
<b>Interviewee 1</b>	DigitalSTROM – electricity control	Connection between all appliances - hub	Low - has to have significant economical benefits	Economics and automation	Interesting to identify consumption and be given savings opportunities
<b>Interviewee 2</b>	None	Possibility to control more oneself	Low - unwilling to give up control	Economics	To little electricity consumption to make it viable
<b>Interviewee 3</b>	Smart security system, electric vehicle	Smart charging of electric vehicle, centre for smart home control	High - only if economically beneficial	Economics and comfort	Low electricity prices and low awareness
<b>Interviewee 4</b>	Digital locks, lighting system, heat control system and hybrid vehicle	Hub for all smart appliances	Limited - only certain functions if economically beneficial	Economics, comfort and simplicity	Has an effect-based tariff. Has a tech-interest
<b>Interviewee 5</b>	Smart lighting system	Smarter awning, time based lighting	Low - unwilling to give up control	Control	Experiences low electricity costs and high awareness
<b>Interviewee 6</b>	Electric vehicle, solar panel and battery storage, security system	Increased automation	High - if economically beneficial	Comfort and economics	Has an effect-based tariff and big interest for new technology
<b>Interviewee 7</b>	None	More automation such as lighting	High	Comfort and automation	Already has low electricity costs
<b>Interviewee 8</b>	None	Automation and security	Limited - depends on economic benefits	Information security, automation and comfort	Importance of data security

<b>Interviewee 9</b>	None	Visualisation and cost efficiency for energy usage	High - cost neutral	Simplicity, economics, transparency and environmentally friendly	Emphasized how both customer and environment should benefit.
<b>Interviewee 10</b>	Smart plugs for lights	Lower electricity cost	Low willingness - need economic incentives	Comfort, control and economics	Likes the idea of better transparency of the house's electricity consumption
<b>Interviewee 11</b>	None	Smart lightning and heating system	High - for the heating system	Comfort and transparency	Has direct heating - expensive during winters
<b>Interviewee 12</b>	Smart heating system	Smart lightning system	Low - Want to feel free with daily activities	Comfort and automation	
<b>Interviewee 13</b>	Smart plugs for lightning	Automated home, for example smart security system	High - but only the heating system	Comfort and Economics	Tech interest as well as environmentally conscious
<b>Interviewee 14</b>	Smart security system and door lock	Centralized app for all smart home appliances	Low - has to have significant economical benefits	Comfort and Security	Electricity prices are too low to give economic incentives
<b>Interviewee 15</b>	None	Smart heating and ventilation system	High - only over the heating system and only if economic beneficial	Comfort, transparency , economics	Direct heating – expensive during winters. Environmentally conscious.
<b>Interviewee 16</b>	Solar panels	Automated system for the solar panel and the grid	High - only with economic incentives	Automation and economics	Environmental interest. Has direct heating.
<b>Interviewee 17</b>	Electrical vehicle	Smart charging tool for the car	High - but only for the car and for the heating system	Automation and transparency	Likes the idea of better transparency of the house's electricity consumption

<b>Interviewee 18</b>	Automated heating system	Smart lightning and garden tools	Low - do not want to give up control	Automation and security	Data security has to be of the highest level
<b>Interviewee 19</b>	Solar Panel and battery storage	An electric vehicle	High - if economic beneficial	Comfort and economics	Tech interest as well as environmentally conscious
<b>Interviewee 20</b>	None	Increased control and monitoring of heating and security	Low - too risky, want to have freedom at home	Comfort	Data about electricity consumption has to be 100% secured
<b>Interviewee 21</b>	None	Smart lightning system	Low - feel uncomfortable with someone having information about electricity consumption	Comfort and security	Would like the transparency of electricity cost, but not give anyone else insight to the data
<b>Interviewee 22</b>	Smart lawn mower, smart sprinklers	Own energy production, such as solar panels	High - if economic incentives exist	Automation and economics	Tech interest as well as environmentally conscious
<b>Interviewee 23</b>	Self-producing wind power	A battery storage, automated heating system	High - wants to sell electricity to the grid	Comfort and economics	Has direct heating and wants better transparency.
<b>Interviewee 24</b>	Smart plugs	Smart security system	Low - does not want to give up control	Comfort and automation	Tech interest as well as environmentally conscious
<b>Interviewee 25</b>	Automated awnings and sensors for lightning	Renewable and self-produced energy	Low - too much risk of errors	Security and comfort	Likes the idea of better transparency of the house's electricity consumption





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